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THE PENNSYLVANIC AMPHIBIA OF THE MAZON CREEK, ILLINOIS, SHALES, ... *Roy L. Moodie.*

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THE PENNSYLVANIC AMPHIBIA OF THE MAZON CREEK, ILLINOIS, SHALES.*

(Contribution from the Zoölogical Laboratory, No. 198.)

BY ROY L. MOODIE.

Plates 1-14.

INTRODUCTION.

THE fossil-bearing nodules from the shales along Mazon Creek, Grundy county, Illinois, have, ever since their discovery, been very prolific in excellently preserved and highly interesting forms of both plants and animals. Among the latter there have been examples of nearly all the groups which one could hope to find in a brackish or fresh-water and inland deposit. These forms range from low down in the zoölogical scale to the forms which must have stood in an ancestral relation to the reptiles. No true reptiles have been discovered in the deposits, although the discovery of such a group there would not be surprising in the least, yet of the greatest interest. A single excellently preserved skeleton of a true reptile is known from the Linton Coal of Ohio, and has been described by Cope, Williston and the writer. Two true reptiles are known also from the Carboniferous beds of Commentry, France, and examples of reptiles are known from the Rothliegenden of Saxony and from the Gaskohle of Bohemia. The lower portions of these latter deposits are undoubtedly of Upper Carboniferous age.

The fauna and flora of the Mazon Creek shales have been described by many authors. Doctor Eastman, in 1902, pub-

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* Received for publication March, 1911.

lished a list[1] of the vertebrates known at that time from these shales. This list included twenty-five species of fishes and a single species of Amphibia, *Amphibamus grandiceps* Cope, which was all that was known of the higher vertebrates from these beds at that time. Since the publication of Eastman's essay the writer has described[2] an additional species from Mazon Creek, *Micrerpeton caudatum.* This form was shown to be an example of the order Branchiosauria. It was the first definite evidence of the occurrence of this order of Amphibia in America, or, in fact, in the Western Hemisphere.

The next year the writer described (Amer. Natl., XLIV, June, 1910, p. 367) and figured another branchiosaurian as *Eumicrerpeton parvum,* from these beds; and the following year he described (Proc. U. S. Natl. Museum, XL, p. 429-433, 1911) and figured further remains of the same species and described a new microsaurian as *Amphibamus thoracatus.*

There have been, thus, up to the present time, four species of Amphibia described from the Mazon Creek shales. These four species are represented by seven specimens. The type of *Amphibamus grandiceps* Cope was destroyed by fire, but there is an excellently preserved specimen of this species in the collection of Mr. L. E. Daniels, of La Porte, Ind. Other examples of the fossil Amphibia of Mazon Creek which have come to the writer's notice are specimens, representatives of the Branchiosauria and the Microsauria, in the collection of Mr. R. D. Lacoe, now the property of the U. S. National Museum. This small but highly interesting collection has recently been loaned the writer for study by Mr. Charles W. Gilmore. This was the sum total of Mazon Creek Amphibia known to the writer until some months ago. In November of 1909 a collection of nodules containing Amphibia was loaned the writer for study through the courtesy of Doctors Eaton and Schuchert, of Yale University. This lot consists of ten individuals, representing seven genera and eight species, all of which, save one, are regarded as unknown and have been described as new. This is an immense addition to our knowledge of the amphibian fauna of the Mazon Creek shales and adds much to our knowledge of the diversity of structure displayed by the Amphibia of the Carboniferous.

The forms described below are entirely unlike any of the forms occurring elsewhere in the Carboniferous or later ages. It has been the writer's good fortune during the past five years to examine all of the specimens of Carboniferous air-breathing vertebrates in North America, with the exception of Sir William Dawson's collection at McGill University. The European forms, as they have been described from time to time, are, unfortunately, known to him only through the literature, with the exception of a small collection of Branchiosauria recently received in exchange from Dr. Hermann Credner. It is hoped that in the near future this may be supplemented by actual observation, and until that time it can not be positively asserted that the forms described below are unlike those already known, but, so far as his knowledge goes, the writer is confident that they are new to science. The characters used for generic distinctions are such that even the most superficial observations must reveal. They are structural ones, and are those which are used by many eminent vertebrate paleontologists at the present time. Unfortunately, we know so little about the development of the class Amphibia that we can not always be sure that our characters are phylogenetic, as they must be to mean anything. So that until some idea of phylogeny is obtained, structural characters must be used which seem to the describer to be of generic significance.

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[1] Eastman, C. R., Journ. Geol., vol. 10, p 585, 1902.

[2] Moodie, Roy L., Journ. Geol., vol. 17, p. 39, 1909.

The Amphibia so far discovered in the Mazon Creek shales, including those described in this paper, are:

1. *Amphibamus grandiceps* Cope, 1865.
2. *Amphibamus thoracatus* Moodie, 1911.
3. *Micrerpeton caudatum* Moodie, 1909.
4. *Eumicrerpeton parvum* Moodie, 1910.
5. *Mazonerpeton longicaudatum* Moodie.
6. *Mazonerpeton costatum* Moodie.
7. *Cephalerpeton ventriarmatum* Moodie.
8. *Erpetobrachium mazonensis* Moodie.
9. *Spondylerpeton spinatum* Moodie.
10. *Erierpeton branchialis* Moodie.

These ten species are distributed among eight genera, five families, and four orders, thus showing the amphibian fauna of Mazon Creek to be a diverse one. The arrangement of the species into groups is given below.

CLASS.: AMPHIBIA, LINNE, 1758.
Subclass: EUAMPHIBIA, Moodie, 1909.
Order: Branchiosauria, Lydekker, 1889.
Family: Branchiosauridæ, Fritsch, 1879.
Micrerpeton caudatum Moodie.
Eumicrerpeton parvum Moodie.
Mazonerpeton longicaudatum Moodie.
Mazonerpeton costatum Moodie.
Order: (?) Caudata, Duméril, 1806.
Family: Cocytinidæ, Cope, 1875.
Erierpeton branchialis Moodie.
Subclass: LEPOSPONDYLIA, Zittel, 1887.
Order: Microsauria, Dawson, 1863.
Family: Amphibamidæ, Cope, 1875.
Amphibamus grandiceps Cope.
Amphibamus thoracatus Moodie.
Cephalerpeton ventriarmatum Moodie.
Family: Molgophidæ, Cope, 1875.
Erpetobrachium mazonensis Moodie.
Subclass: STEGOCEPHALA, Cope, 1868.
Order: Temnospondylia, Zittel, 1887.
Suborder: Embolomeri, Cope, 1885.
Family: Cricotidæ, Cope, 1884.
Spondylerpeton spinatum Moodie.

The discovery of the embolomerous amphibians in the Carboniferous fauna is not new, since the first embolomerous form known in North America was described from the deposits on Salt Creek, Illinois, as *Cricotus heteroclitus*, by Cope. Later the same or a closely related form was discovered in Texas by Cope and Case and in Kansas by Williston. The form described here is, however, much more primitive than any of the species of *Cricotus*. The rachitomous forms of Amphibia are known from the Carboniferous of North America and Europe through the researches of Fritsch and Case.

The content of the amphibian fauna of the Mazon Creek shales is peculiar on account of the presence of the four species of Branchiosauria. Unless Dawson's *Sparodus* is an example of this group, the forms in the Mazon Creek fauna represent the only known occurrence of this order in North America. Dawson was himself doubtful about the identity of the remains which he referred to *Sparodus*. Judging from his figures, there is a possibility that he may be right, since the form of the interclavicle is decidedly branchiosaurian, as we know the form of that element among the European species. Beside the presence of the Branchiosauria, the Mazon Creek amphibians differ from the Canadian species in the almost total absence of any scaly covering such as occurs in *Dendrerpeton* and *Hylerpeton,* although *Micrerpeton* has very small scales over the body and tail. Furthermore, the Canadian species are more terrestrial than those from Mazon Creek, which, judging from their form, were either entirely aquatic or only partially terrestrial. The size of the members of the two faunas differs in no great degree. Large and small members are found in both localities. The Joggins Amphibia are hardly well enough known to judge their relationships other than those of an ordinal or family rank. These relations will be given in another paper.

The Linton fauna, which is more fully described in another paper, is quite unlike the Mazon Creek fauna. This is evident by the absence of branchiosaurian forms from the Linton deposits and by the presence of the legless Microsauria and the Proteid form *Cocytinus,* which is paralleled by *Erierpeton* in the Mazon Creek fauna. The limbed Microsauria also differ in a marked degree, in that the Mazon Creek forms have a strong tendency toward the Reptilia, as illustrated in the Amphibamidæ, *Amphibamus* and *Cephalerpeton.* The Linton fauna shows a wide divergence of types, illustrating different phases of amphibian development, and in the tendency of certain groups, such as the families Tuditanidæ and Macrerpetidæ, to approach the Stegocephala proper and through them certain of the stegocrotaphous reptiles. The Linton fauna is distinctive too in the abundant presence of such highly developed swimmers as *Œstocephalus, Ptyonius, Phlegethontia* and *Ctenerpeton,* and as such is interesting in displaying parallel development of the same structures in forms which are really widely separated in structure.

The fauna of the Cannelton slates is not very different from that of Linton, and the remarks made concerning the relationship of that fauna to the Mazon Creek fauna will also apply with reference to the Cannelton fauna. Outside of these four deposits, there are several minor deposits which have furnished amphibian remains, none of which agree in any essential respect with the Mazon Creek fauna. Attention has already been called to the fact of the occurrence of the embolomerous forms in the Mazon Creek, the Pitcairn, Pa., the Kansas, and the Salt Creek, Illinois, faunas.

A view of the entire amphibian fauna of the North American Carboniferous, as we know it at this time, shows us that the separate faunas were local, and as such indicate the ancient history of the group at that time. Such a high degree of developmtnt and such a wide dispersal of types would indicate a long antecedent history. Possibly the Amphibia of the Mississippian rocks will yield forms which will connect these local faunas; possibly we may have to look to the Devonian for these connections. The early Mississippian and Devonian forms are already indicated by footprints, but as yet we know nothing of the structure of the creatures which made the footprints.

DESCRIPTIONS OF GENERA AND SPECIES.

Genus ERIERPETON—New Genus.

All of the examples of Amphibia loaned the writer by the Yale University Museum are capable of identification. One of the most unusual forms is represented by a distinct impression on a weathered ironstone nodule from which all the bony matter had become eroded. It is so unusual in form and in the characters which it presents that it is deemed worthy of description. Since it is totally unlike anything described, it must be placed in a new genus, for which the term *Erierpeton* is proposed. The name refers to its early appearance. The specimen in question is No. 801 (222)5 of Yale Museum. The nodule which contains the impression is some three inches in long diameter.

The generic characters are found, first of all, in the presence of hyobranchial arches, which indicate its relationship to the formerly described *Cocytinus gyrinoides* Cope, from the Carboniferous of Ohio. The only other known extinct genera of Caudata which possess, or at least have preserved, the branchial arches are the Jurassic *Hylæobatrachus* from Belgium and *Lysorophus* from the Permian of Texas. The present form is widely distinct from both of these genera in the shape of the mandible and the form and arrangement of the hyobranchial arches. The new genus finds its closest ally in *Cocytinus* in the family Cocytinidæ which possibly belongs in the order Caudata and in the suborder Proteida of Cope.

Erierpeton branchialis, New Species.

(Plate 1, fig. 3; plate 2, fig. 1.)

The amphibian remains which are designated by the above name consist of a distinct mandible and some rather indefinite body impressions. Three elongate impressions occur between the rami of the mandibles, which, I suppose, must represent hyoid bones belonging to the branchial arches. The lateral elements are paired and the median impression is straight and lies between the paired portions of the hyoids. The paired portions probably represent the hypohyals, or hypohyals plus the ceratohyals, and the unpaired portion the first basibranchial, according to the nomenclature of Wiedersheim (Comparative Anatomy of Vertebrates, 1897, p. 86). If the impressions have been correctly interpreted, the present specimen is of very great interest since it is the first evidence we have of the hyobranchial arches in the Amphibia of Mazon Creek, and the second in the Carboniferous of North America. Dawson doubtfully identified some elements of the Joggins Amphibia as hyoids, but was uncertain as to their position. Cope described fully the well-developed hyobranchial apparatus of *Cocytinus gyrinoides* from the Coal Measures of Ohio. Among other Paleozoic Amphibia, Williston has described branchial arches in the peculiar form *Lysorophus tricarinatus* Cope, from the Permian of Texas.

The form of the impression of the mandible in the present specimen is unlike anything known to the writer among other Carboniferous or later Amphibia. The rami are long, slender, deep, slightly curved and pointed anteriorly. The anterior symphysis was not a complete sutural union, but was occupied partly by cartilage or connective tissue.

There are no definite traces of appendicular structures. The traces of the body, plate 2, fig. 1, indicate an elongated, rather slender animal, but further than that nothing can be said in regard to its structure.

The occurrence of a typically caudate form in the Carboniferous is unusual, and complicates still further our understanding of the origin and relationships of the early Amphibia.

MEASUREMENTS OF THE TYPE OF ERIERPETON BRANCHIALIS MOODIE.

	mm.
Length of entire impression	50
Length of mandible along median line	10
Width of mandibular ramus	9
Length of basibranchial	2.5
Width of basibranchial	.75
Length of hypohyal	2.4
Width of hypohyal	1.5

Genus MICRERPETON, Moodie, 1909.

This genus was established by the writer on a single excellently preserved specimen (No. 12,313, University of Chicago). The genus is readily distinguished from other members of the Branchiosauridæ by the large size of the orbits, the short, heavy limb bones, the slender ilium and the expanded, elongate and flattened tail.

Micrerpeton caudatum Moodie, 1909.

There is but a single species known. It is fully described in previous papers. (Journal of Geology, vol. xvii, No. 1, pp. 39-51, with seven figures, 1909; Journal of Morphology, vol. xix, No. 2, pp. 516-520, with three figures, 1908.)

Genus EUMICRERPETON, Moodie, 1910.

Amer. Natl., vol. XLIV, June, 1910, p. 367.

This genus is based on well-preserved remains of three individuals from the Mazon Creek shales. One of the specimens represents, apparently, an adult, and the others are immature. The manner of the impressions resembles in a marked degree those described by Thevenin from the Commentry beds of France (plate 14). The nodules which inclose the remains measure, respectively, two and one-quarter and two and one-half inches in long diameter.

The generic characters are found in the very broad posterior table of the skull, with its short longitudinal length, the reduction of the tympanic notch and the short length of the body. The body length of *Eumicrerpeton* is as 2 to 4, while that of *Micrerpeton* is as 2 to 5, and that of *Branchiosaurus fayoli* is as 2 to 4⅓. The entire impression of the branchiosaurians from Saxony are not preserved, so that comparative measurements are not possible. Other generic characters are found in the sharp supratemporal angle of the skull, and it is to be distinguished from *Micrerpeton* especially by the short, stumpy limb bones. Its distinctions from the genera of European Branchiosauria are the same as those which distinguish it from *Branchiosaurus,* to which it is closely allied. The narrow, elongate eye, placed close to the edge of the skull, is a character not observed hitherto in the Branchiosauria. It recalls the condition described by Credner for the young forms of *Branchiosaurus amblystomus* Cred.[3]

Eumicrerpeton parvum Moodie, 1910.

(Plate 3, figs. 3 and 4; plate 4; plate 5, fig. 1; plate 6, figs. 1 and 2.)

The specific characters are found in the anatomical details. The impression of the outline of the entire body is preserved in both animals, and in both are found impressions and molds of the alimentary tract which in the younger animal are remarkably complete and instructive.

The impression of the larger animal, which is probably an adult, presents the following elements: the entire skull; both humeri; impressions of posterior and anterior ventral armature; portions of the alimentary canal; one femur; portions of a fibula and tibia; and the entire impression of the tail, on which, as in *Micrerpeton caudatum* Moodie, there occur two definite dark lines, one beginning at the tip of the tail and running obliquely along the tail to where the impression is broken at the anal region; the other beginning at a distance of four and one-half millimeters from the tip and running almost parallel with the median line. These two lines undoubtedly represent the lateral line system.

The skull is especially noted for its shortness and the great posterior width, as well as for the almost entire absence of the tympanic notch. The pineal foramen is located on a line with the posterior border of the orbits. The eyes themselves are narrow and acuminate at each end, with a pronounced convexity inward and a flattening outward. They are located on the very border of the skull, but relatively further posterior than in *Micrerpeton.* No sclerotic plates are evident. The median suture can be indistinctly observed running the entire length of the skull. The sutures bounding the outside of the frontals and the squamosals are partially evident but not satisfactorily preserved. The mandible is represented by a mold which in a wax impression shows short, stumpy teeth.

Posterior to the skull, at a distance of one millimeter, there are two sharp impressions, which may represent the anterior edges of the interclavicle, or they may be branchial elements. They are distinctly curved, however, and probably represent portions of the interclavicle. A wax impression does not show a discrete structure, but the boundaries of some larger element. No other remains of the pectoral girdle can be discerned. The humeri are short and relatively thick. Wax impressions show them to have had truncate or slightly concave ends, thus indicating the absence or slight development of endochondrium. No other elements of the arm are preserved.

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[3] Zeitschrift d. Deutsch. Geol. Gesellschaft, 1886, Th. VI, Taf. XVI, fig. 1,

The ventral armature is preserved in two small patches, and these show the chevron-shaped rods to have been very fine—much more delicate than in *Micrerpeton.*

The body impression is very interesting, both as showing the form of the body and because in it are preserved the impressions of the larger portion of the alimentary canal. The form of the body can best be discerned by reference to the figures. (Plate 3, figs. 3, 4; plate 6, figs. 1, 2.)

The portions of the alimentary canal preserved consist of the greater portion of the stomach, three coils or loops of the small intestine, the rectum, and a pit which undoubtedly represents the anal opening. The anus is found at a distance of 16 mm. from the tip of the tail, and is somewhat removed from the body portion, as in modern salamanders. On each side of the posterior end of the rectum there occurs a pair of enlargements, which probably represent the oviducts at their posterior extremity.

The tail impression is more acuminate than in *Micrerpeton,* but shows the same structures as that form, *i. e.,* the lateral lines, which have already been mentioned. *Micrerpeton* was a more rapid swimmer than the present form, on account of the greater development of the tail. The impression of an elongate femur and the heads of the tibia and fibula of the left side are preserved.

The second specimen of the species (No. 802, Yale Museum) shows much the same characters as the specimen already described, except that there are preserved impressions of small, blunt teeth on the mandible. The two humeri and the femur of the left side are preserved, and the interclavicle is represented by an identical impression as in the first described specimen. The tail impression, although similar in form, does not exhibit so much of the structure of the lateral lines. The present specimen is considered as more immature than the former, on account of its smaller size. There are no positive evidences in either specimen of branchial arches.

The matter of especial interest in connection with the second specimen is the remarkably perfect preservation of the alimentary canal. It is entire except for the very anterior end of the œsophagus. The posterior portion of the œsophagus, which measures three and one-half millimeters, is clearly preserved. Its anterior end is thrown around posteriorly, and indicates that this end was loosened after death and became displaced before preservation. The length preserved possibly represents the entire œsophagus. The œsophagus is constricted before it enters the stomach, which shows the usual curvature found in modern salamanders. The stomach measures six millimeters in length by two in greatest breadth. It consists of a single enlargement, as in the modern *Ambystoma punctatum.* The stomach enlarges somewhat toward the pyloric end, and then very gradually constricts to the pyloris. Three diameters of the small intestine can be discerned. The most anterior one, corresponding with the duodenum, is segmented, as though the intestine were filled with food substance. The remainder of the intestine, corresponding to the ileum, is looped in the form of two figures "8," which are superimposed, with the upper portions of the "8" at right angles to each other. The rectum is clearly discernible, though its lower end is somewhat obscured by having the lower portion of the upper loop of the intestine lying over it. The anus lies at a distance of one and one-half millimeters posterior to the line from the upper end of the femur, and is quite well back on the tail, as in modern salamanders. In this specimen also occur two oval bodies, which may be identified as the lower ends of the oviducts; thus indicating, in all probability, that the animal was a female.

A dissection of several species of modern urodeles has resulted in the discovery that the adult condition of the alimentary canal of all species dissected—*Ambystoma punctatum, Necturus maculosus, Diemyctylus torosus,* etc.—is much more complex than that exhibited by the specimen under discussion. A very near approach to the condition found in *Eumicrerpeton parvum* is found in an immature branchiate individual of *Diemyctylus torosus,* 56 mm. in length, from a fresh-water pond on Mount Constitution, on Orcas Island, Puget Sound, Washington.

The similarity of intestinal structure is of considerable importance to our understanding of the relationship existing between the Carboniferous Branchiosauria and the modern Caudata. This fact only confirms other arguments, offered in another place, concerning their immediate relationship. (American Naturalist, vol. xliv, June, 1910.)

The branchiosaurian affinities of the present species are almost too evident to need discussion. The entire structure is essentially similar to that of other genera of the order.

MEASUREMENTS OF EUMICRERPETON PARVUM MOODIE.

Specimen No. 803, (222) Yale University Museum.

	mm.
Length of animal	37.5
Length of skull	4.5
Posterior width of skull at table	6
Long diameter of eye	1.75
Transverse diameter of the eye	.65
Length of left humerus	1.5
Length of femur	1.75
Width across base of tail impression	3.5
Length of tail from base to tip	17
Number of ventral armature rods in 1 mm	10

Measurements of second specimen, No. 802, (471) Yale University Museum.

	mm.
Length of animal	30
Length of skull	4
Posterior width of skull	5
Length of œsophagus	3.5
Length of stomach	6
Width of stomach	1.33
Estimated length of intestine	18
Width across base of tail impression	2.5
Length of tail from base to tip	7

Eumicrerpeton parvum Moodie (an additional specimen).

(Plate 5, fig. 1.)

After the above had been written the writer received from Mr. C. W. Gilmore, of the U. S. National Museum, an additional specimen of this species. It is No. 4400 of the U. S. National Museum. The additional specimen serves to substantiate the above-described genus and species, and shows more clearly characters which are distinct from *Micrerpeton*, the genus to which the present form is most nearly related.

The present specimen is almost as perfectly preserved as was the specimen of *Micrerpeton caudatum* Moodie. When the nodule containing the fossil was received the tail was embedded in matrix, but by careful use of chisel and hammer it was possible to lay bare the whole tail, the tip of which ends on the very edge of the nodule. This was at once perceived to be precisely similar to that of the above-described specimens. The skull structure, the intermediate position of the pineal foramen, the epiotic notch and the shape of the skull are so exactly similar to those of *Eumicrerpeton parvum* that the specimen was unhesitatingly referred to that species.

Most interestingly, too, the present specimen has the alimentary canal preserved almost as perfectly as in the other two specimens; so that the three specimens of this species now known show the alimentary canal. The present specimen is, however, much more developed than the other two, if we may judge from the relative sizes. There is not the slightest trace of branchiæ in any of the specimens. The matrix does not preserve the skeletal elements as well as does the hard dolomite from Saxony, in which Doctor Credner found such excellently preserved branchiæ.

The present specimen is nearly half again as long as the smallest of the above-described specimens, and the skull is proportionately longer and wider. There is preserved also an impression of the anterior edge of both clavicles, as has been described for the Yale specimens; no other portion of the pectoral girdle is preserved. The right humerus is imperfectly preserved, as is also the right femur and tibia; other than these the fossil is merely an impression.

The skull is so nearly like what has been described for the Yale specimens that additional description is unnecessary. The pineal foramen is quite large, and lies on a line which cuts the orbits into equal longitudinal parts. The interorbital space is about equal to the long diameter of the orbit, as in the Yale specimens. Traces of sclerotic plates are observed in the left orbit, but they are quite imperfect.

The alimentary canal is unlike that of the Yale specimens, in that the INTESTINE is longer and much more convoluted. It lies in five longitudinal folds and ends in an enlarged cloaca, near which there are impressions of two glands, or they may be the posterior ends of the oviducts, as was suggested for the Yale specimens. Like the Yale specimens, the œsophagus is displaced and partially obscured. The creatures undoubtedly fed on small plants and animals, much as do our recent salamanders. The alimentary tract is preserved fully extended.

MEASUREMENTS OF ADDITIONAL SPECIMEN OF EUMICRERPETON PARVUM MOODIE.

(Cat. No. 4400, U. S. N. M.)	*mm.*
Length of entire animal	45
Length of skull	6
Width of skull	9
Transverse diameter of orbit	1.50
Long diameter of orbit	2.25
Interorbital space	2.50
Diameter of pineal foramen	.50
Length of body from back of skull to pelvis	22
Greatest width of body	9
Length of tail	16
Width of tail at base	5
Length of humerus	3
Length of femur	2.50
Length of tibia (fibula ?)	1.75
Length of stomach	7
Width of stomach	3
Length of intestine (estimated)	56
Width of intestine	1

Genus MAZONERPETON, new genus.

It was very gratifying to discover among the remains loaned the writer by the Yale Museum other specimens exhibiting characters of the Branchiosauria, for our knowledge of this order of Amphibia is as yet very incomplete in North America. The specimen represents by far the largest of the group discovered on this continent. It is more than twice as long as the specimen of *Eumicrerpeton parvum* and fully one-third longer than *Micrerpeton caudatum.* It is, however, distinctly a branchiosaurian. The ordinal characters are discovered in the heavy, straight ribs, attached to the transverse process of the centrum; in the low degree of development of the vertebræ; in the structure of the skull and the ventral armature, and in the degree of ossification of the limb bones.

It may be generically separated from other known Branchiosauria found in North America by the great length of the dorsal region, and by the elongate tail with its well-developed caudal ribs. It is not so readily separable from the Branchiosauria of Europe. It is most closely related to *Branchiosaurus amblystomus* Credner of the Permian and Carboniferous of Saxony. From this genus, however, *Mazonerpeton* may be distinguished by the reduction of the posterior tympanic notch, the broad nature of the scapula, the elongate interclavicle and the slender ilium in the present form. The number of dorsal vertebræ is identical in the two genera.

The genus is so closely allied to *Branchiosaurus* of Europe that the two species here described must be located in the family Branchiosauridæ.

Mazonerpeton longicaudatum new species.

(Plate 3, figs. 1 and 2; plate 7, fig. 3; plate 10.)

The remains on which the above species is based consist of the following elements: an incomplete skull, nearly the entire vertebral column, consisting of cervical, dorsal, sacral and caudal vertebræ, 36 in number; several ribs preserved on each side of the vertebral column, a portion of the ventral armature, the scapulæ, a clavicle, the interclavicle, both humeri, the radius and ulna of one side and the ulna of the other, portions of both hands, the ilium of the right side, both femora, and a partial impression of the left tibia.

The skull is unfortunately very poorly preserved. Enough remains, however, to determine the essential characters. The skull bones, unlike any other American branchiosaurian, have an ornamentation consisting of sharp pits and elevations, which in places have a quincuncial arrangement and in others take the form of definite lines of pits or tubercles similar to the condition found in many of the Microsauria. The orbits are large and are situated back of the median transverse line of the skull. They are almost circular in form and contain six elongated sclerotic plates very closely arranged around the borders of the right orbit. The plates are twice as long as wide. The interorbital width is one and one-fourth as great as the transverse diameter of the orbit.

Not many of the sutures of the skull are discernible. Portions of the frontals, the nasals, the prefrontals, the parietals and the supratemporals can be identified. Their arrangement is shown in figure 3, plate 7. There is a decided posterior table to the skull, with a truncate posterior border. The tympanic notch is shallow, with its outer border not so well protected as in *Branchiosaurus*.

The cervical vertebræ are incomplete, but their number was four or five, as in *Micrerpeton.* The structure of the dorsal vertebræ is also uncertain, although the shape can be discerned. The vertebræ are short and thick, very unlike the long, cylindrical vertebræ of *Cephalerpeton.* The heavy transverse process is quite evident on the best preserved vertebræ. This process recalls that described by Credner for the Saxony Branchiosauria. Several of the vertebræ show the attachment of the ribs to this process. The ribs of the caudal region recall very strongly those of *Branchiosaurus.* They are quite heavy in the anterior caudal region and then diminish rather rapidly to the point where the tail is broken and lost.

The ventral armature is represented by a patch of chevron rods twenty-one millimeters in length. The rods take a very peculiar form. They are short, crescentic bundles of fine rods, hair-like in appearance. In one of the bundles I count five smaller rods. The bundles are arranged in rows similar to the pattern so characteristic of the Carboniferous Amphibia, as described elsewhere. The patch of ventral armature preserved belongs to the abdominal region, so nothing can be told of the gular and thoracic rods. A single row of the crescentic bundles measures 11 mm.

Both scapulæ are preserved in their entire form. They are quite different from those of any other genera. They resemble a broad crescent with a posterior concavity and an anterior protuberance. The articular surface of both scapulæ is obscured. Vascular foramina occur near the base of both scapulæ. There are three of them in the right element, arranged in the form of an isosceles triangle. The morphology of these three foramina is uncertain. They have never before been observed among the Carboniferous Amphibia, and, so far as I am aware, they are entirely unknown among the higher vertebrates.

The temnospondylous Amphibia of the Carboniferous and Permian possess, in the coössified scapula-coracoid, three foramina, very similar to the present ones, but they are confined to the coracoidal region, and in the Branchiosauria the coracoid, as identified by Credner, is a free element, although I have never been sure with regard to its identity among American forms. Williston, in *Trematops*, has called these foramina the glenoid, supraglenoid and supracoracoid foramina

(Journ. Geol., xvii, No. 7). These are not, however, to be correlated with the three foramina above mentioned, since in the Temnospondylia the foramina belong with the coracoid and not with the scapula. The condition of the Temnospondylia occurs in the bony fishes, *Xiphactinus audax* Leidy; and an analogous condition obtains in the reptiles, as in the mosasaurs and dinosaurs, where the separate coracoid is pierced by foramina. Doctor Williston informs me that the foramina are also found among the Cotylosauria, where the condition is not far different from what it is in *Eryops*.

Near the outer end of the right scapula there is a large fragment preserved which, I think, must be the misplaced clavicle. It is obscurely triangular, or, more exactly, spatulate. The interclavicle is represented by fragments only. It seems to have had a narrow form.

The humeri recall those of *Micrerpeton.* They are somewhat elongate and apparently cylindrical in their normal condition, though somewhat flattened in the fossil. The shaft is considerably constricted at the middle, and the ends are expanded, in which expansion the lower end exceeds. The ends are abruptly truncate, indicating a small amount of endochondral ossification or its entire absence.

The mesopodial elements, unlike what has been described for *Cephalerpeton,* are quite dissimilar in form, recalling the condition in *Mesosaurus brasiliensis* McGregor. The larger element I take to be the ulna. It has the lower end greatly expanded and the shaft is curved outward. It resembles very much a reptilian ulna.

The radius is much smaller than the ulna, lacks the lower expansion, and is shorter by one millimeter. Its ends are abruptly truncate.

The carpus is represented merely by a blank space. There are no evidences of impressions of cartilage in the sandstone. The hand of the left side contains four digits. There are two phalanges preserved in the first digit, including the sharp-pointed terminal phalanx. The second digit has only the metacarpal. The third has the metacarpal and the first phalanx, which does not differ in form, but only in size, from the metacarpal. The fourth digit contains only the metacarpal. No definite evidence of more than four digits has ever been given for the hand of the Branchiosauria. Of the right hand there are portions of three digits preserved, including three metacarpals and one phalanx. In structure they are not different from those of the right hand.

The ilium of the left side is preserved, apparently entire. It is elongate and cylindrical. Its upper end lies adjoining the twenty-eighth vertebra.

The head of the femur lies close to the lower end of the ilium, so that that element must have been suspended in the flesh much as in the modern salamanders. It could not have been of much use in support. The form of the femur is not unlike that described for the humerus, save that its lower end is smaller than the upper, while in the humerus both extremities are alike. A portion of the right femur is preserved extending in an opposite direction to the left. No portions of the leg or foot are preserved.

MEASUREMENTS OF THE TYPE OF MAZONERPETON LONGICAUDATUM MOODIE.

	mm.
Length of entire specimen	64
Length of portion of skull preserved	6.5
Posterior width of skull preserved	7
Width across orbits	11
Long diameter of the orbit	3
Transverse diameter of orbit	1.75
Interorbital width	4.75
Length of dorsal vertebræ	48
Length of caudal series	11
Length of anterior dorsal vertebra; 1 centrum	2
Length of anterior dorsal rib	4
Length of anterior caudal rib	1.75
Length of scapula	5
Greatest width of scapula	4.25
Probable length of interclavicle	6
Width of interclavicle	3
Length of clavicle	4.5
Width of clavicle	1.5
Length of right humerus	6
Distal width of humerus	2
Length of ulna	3.25
Distal width of ulna	1
Length of radius	3
Width of carpal space	2
Length of metacarpal	1.74
Length of first phalanx	1.75
Length of distal phalanx of right hand	.35
Number of bundles of chevron rods in 1 mm	4
Length of ilium	2.25
Length of femur	4
Proximal width of femur	1.50

The type is specimen No. 795 (1234), with obverse, of the Yale University Museum. Collected at Mazon Creek, Grundy county, Illinois.

Mazonerpeton costatum new species.

(Plate 2, fig. 3; plate 8, fig. 4; plate 9, fig. 2; plate 10)

The remains on which the present species is based are inclosed in a much-fractured nodule. The parts of the animal which have been identified are as follows: A part of the skull and left mandible, two clavicles, a humerus, impressions of several vertebræ, a portion of the dorsal region of the body, with several ribs, two portions of the caudal region, with several ribs, and some unidentified fragments.

The animal, from the shape and form of the ribs, is undoubtedly a representative of the Branchiosauria, since short, heavy, straight ribs have not yet been found to be associated with other than branchiosaurian structures. Its association in the same genus with *Mazonerpeton longicaudatum* is held to be correct, on account of the resemblance in structure of the pectoral elements, the form of the humerus, and the length of the tail. The present species is about one-half larger than *Mazonerpeton longicaudatum*, and the animal which represents the species perhaps attained a length of four and one-half inches, while the length attained by the type of *M. longicaudatum* was not more than three inches. The tail of the present species is very long and slender, more elongate than in any other described branchiosaurian.

The part of the skull preserved is very unsatisfactory, and, aside from the fact that it seems to represent the under side of the left half of the skull, little can be said. Portions of three sutures can be observed, but what sutures they are is undetermined. The left mandible lies crushed on the edge of the skull and partially obscures what little there is of that structure. The slightly curved impression, from which the bone has been either broken or weathered, measures thirteen millimeters in length by three in posterior diameter by one in anterior diameter. These measurements show the element to have been slender and pointed anteriorly.

Very little accurate information can be derived from the study of the vertebral column of the specimen. The dorsal vertebral formula can not be made out, since only a portion of the length of that region is preserved, and only a few rather indefinite impressions can be discerned. These impressions show the vertebræ to be short and higher than in most Branchiosauria.

The caudal series is represented by two sections. One of these sections is apparently from near the base of the tail, judging from the size of the caudal ribs preserved. The other section is from near the tip of the tail, and it shows the constituents to have been long and slender. Ribs are apparently absent on this section. The position of the two caudal sections shows that when the animal died it was coiled up much like a snake, so that in the fractured nodule three sections of the body are preserved. The tail was probably half as long again as the body.

The ribs throughout the body are short, heavy and straight, with, in the dorsal series, a lateral and a distal expansion, which is taken as a distinctive specific character. Judging from imperfect impressions in the dorsal series, the ribs were attached to a transverse process of the centrum, thus agreeing with other branchiosaurians in this respect. The ribs show a progressive decrease in length from the cervical region to the point of their disappearance on the tail.

The pectoral girdle is represented by two elements, one of which is certainly the right clavicle, and the other is possibly the left clavicle, though its form is somewhat distorted by pressure. Both elements are in the form of an elongate spatula, with the dorsal surface greatly concave and the inner end acuminate.

The right humerus is imperfectly preserved, though the impression allows one to gain an exact knowledge of its form. It lies under the right clavicle. Its ends are truncate with a contracted shaft and expanded extremities. The bone was apparently hollow.

In another nodule (No. 804, Yale Museum) there is a single bone preserved, which resembles to a great extent a rib of the present species, although somewhat larger, and it has been provisionally identified as such. The element is very slightly curved, but it shows the expanded head of this species. (Plate 2, fig. 3.)

MEASUREMENTS OF THE TYPE OF MAZONERPETON COSTATUM MOODIE.

	mm.
Length of portion of skull preserved	14
Length of right clavicle	16
Width of right clavicle	4
Length of dorsal region represented	30
Length of cervical rib	8
Length of dorsal rib	6.5
Length of caudal rib	3
Length of caudal portion of the body preserved	55
Length of mandible	15
Greatest width	6
Length of right humerus	10
Greatest width of right humerus	2

The type is No. 800 (777) of the Yale University Museum. Collected at Mazon Creek, Grundy county, Illinois.

MEASUREMENTS OF SPECIMEN NO. 804 (332).

	mm.
Length of rib	11
Width of head of rib	2
Diameter of shaft	1

Amphibamus grandiceps Cope, 1865.

(Plate 1, figs. 1 and 2; plate 5, fig. 3; plate 7, fig. 1; plates 11, 12, 13.)

The collection of Carboniferous Amphibia loaned the writer for study by the Yale Museum contains an unusually perfect example of *Amphibamus grandiceps* Cope. The skull is nearly complete, although the sutures are indistinct. The following parts have been identified in the specimen: the greater part of the vertebral column, ventral armature, ribs, portions of the pectoral girdle, the pelvic girdle, and all four limbs, with the hands and feet in an unusually perfect condition, all very clearly and distinctly shown on a nodule from the Mazon Cheek shales of Illinois. The specimen was collected near Morris, Illinois, in 1870.

The writer (1909) published a restoration of this species, in which he gave to the vertebral column twenty-six vertebræ, the exact number being at that time uncertain. Professor Cope (1865) in his original description gave the number as thirteen between the interscapular region and the sacrum. Hay (1900) thought the number was less than twenty. The present specimen shows that there were twenty-two in the presacral region, not including the sacral vertebra; thus showing that in two cases too few vertebræ and in the third case too many vertebræ were assigned to the vertebral column, The author's published restoration gave too great a length of tail. The present specimen shows only ten cadual vertebræ, the most anterior of which are provided with short ribs.

One of the most interesting features of the present specimen of *Amphibamus grandiceps* Cope is the preservation of a small patch of skin, evidently from the back. It lies off to one side, near the head, as though the skin had been loosened and floated away from the body or was moved in some manner. The remnant measures 5 mm. in length by 3 mm. in width. The fragment shows the skin to have been made up of tuberculated scales, four of which occur in the length of one millimeter. The scales are somewhat hexagonal, almost rounded, and were relatively quite thick. They lie in a close mosaic.

The cranial structure presents no new features. There are evidences of twenty small, oblong, sclerotic plates preserved in the right orbit. These form about two-thirds of the circumference of the iris, so that twenty-nine or thirty was probably the correct number of these plates. Their position near the center of the orbital space shows clearly that they were sclerotic plates, and not palpebral scales, as Professor Cope thought they might be from his study of the type. The obverse of the specimen shows that the skull bones were pitted, especially in the nasal region, as Hay has described for the specimen in the possession of Mr. Daniels. The sutures are very indistinct and uncertain and can not be described. They are well known, however, in other specimens.

The present specimen adds to our knowledge of the ventral scutellæ, as is shown in figure 1, plate 7. The plates of the throat, chest and belly have different directions. The arrangement of the plates on the throat and chest is almost exactly the reverse of what Credner has described for *Branchiosaurus amblystomus* Cred. On the throat, in the present form, the chevron points anteriorly, and it is the anterior prolongation of the belly scutes with the posterolateral projection of the gular plates which forms the chest and arm scutellation. The belly chevrons point anteriorly, as in the species from Saxony. The rods formed by the scutes are straight, and not curved as in *Branchiosaurus*. The entire ventral armature preserved is misplaced to the left of the animal, and only the anterior portion is preserved, containing a length of 18 mm. There are three scutes to the millimeter.

Nothing new can be ascertained of the structure of the pectoral girdle. Portions of the scapulæ, clavicles and interclavicle are represented, and perhaps the coracoid is indicated by a fragment.

The specimen in hand completes in a very satisfactory manner our knowledge of the structure of the pelvis. The relations, form and structure of the ilium, ischium and pubis are now known quite certainly. The form of the ilium as shown in previous restorations was slightly inaccurate. It was made a little too long and too curved. It is, instead, rather short and nearly straight, with the ends expanded. Heretofore nothing was known about the ischium, but the present example shows very clearly the form of that element on both sides of the vertebral column. Its form is almost identical with that of *Paleohatteria longicaudata* Credner, from the Rothliegenden of Saxony. They are apparently approximate in the median line, though this character is somewhat obscured by the impressions of the caudal vertebræ. Its relation with the ilium, other than that it was posterior to it, is uncertain. All three of the pelvic elements were undoubtedly hung loosely in the flesh of the animal, as in modern salamanders, since none of the elements present any marked articular surfaces.

The structure of the sacral vertebra and the sacral ribs still remains to be determined. There seems to have been but a single pair of sacral ribs, but the specimen is too obscured to shed much light on that point.

Nothing new is added to our knowledge of the arm. The number of phalanges can not be ascertained. Two of the digits are preserved entire, and there is nothing in their structure to contradict the number given in the restoration which is herewith republished. Each hand has a single digit of four segments preserved. They undoubtedly represent the third digit in each case.

The elements of the leg and foot are as they are given in the restoration. The right foot is preserved almost entire, and the digits have the formula 2-2-3-4-3. The distal phalanges of the third and fourth digits are lost. There are five digits in the foot.

The fifth anterior dorsal vertebra has a pair of long, curved ribs attached intercentrally. The ribs have the same bicipital appearance as observed in Mr. Daniels' specimen. They are present throughout the dorsal series, apparently missing from the lumbar region, and appearing again in the caudal region. How much of this is due to accident is hard to determine.

The structure of the vertebræ can be partially observed in the specimen. The neural spine was a long, low crest, which ran the entire length of the centrum, with a median elevation, so that on lateral view the spine would be triangular in form. The body of the centrum is expanded laterally into a diapophysis which projects anteriorly. In the posterior region of the dorsal series the mold of the interior of the vertebra shows that the notochord was largely persistent and that the osseous portion of the vertebra was but a thin shell.

The structure of the zygapophyses can not be determined. That they were dorsal in position is, however, evident from several vertebræ. The points of these structures project laterally. There is a notch between the anterior zygapophysis and the roof of the neural canal.

The restoration of the skeleton of this species, given on plate 12, is a summary of existing knowledge of the skeletal anatomy of the genus. Much remains to be determined, such as the arrangement of the scutes of the ventral armature, the anatomy of the pectoral girdle, and the more exact knowledge of the feet and vertebræ. The restoration gives approximately the form of the body and the condition of the skeleton as we know it at present.

MEASUREMENTS OF THE SPECIMEN OF AMPHIBAMUS GRANDICEPS COPE.

	mm.
Length of skeleton	67
Length of skull	15
Posterior width	15
Depth of tympanic notch	4
Width of tympanic notch	6
Long diameter of the orbit	7
Transverse diameter of the orbit	5.5
Interorbital width	4.5
Diameter of the pineal foramen	.75
Length of cervical series of vertebræ	9
Length of dorsal series	35
Length of caudal series	13
Length of centrum of the dorsal series	1.5
Length of a dorsal rib	3.5
Length of arm	20
Length of humerus	7
Length of radius and ulna	4
Width of carpal space	3
Length of third digit	5
Length of leg	25
Length of ilium	3
Length of femur	9
Length of tibia and fibula	5
Length of carpal space	4
Length of first digit	3
Length of second digit	4.5
Length of fourth digit	7
Number of ventral scutellæ in 1 mm	3

The specimen, with obverse, is No. 794 (1234) of the Yale Museum.

Amphibamus thoracatus Moodie, 1911.

(Plate 5, fig. 2.)

The chief diagnostic characters which will at once distinguish the species are: the elongate arm, the large interclavicle, the shape of the vertebra, and the triangular skull.

The portions of the animal which are preserved are: the impression of the skull with one orbit, the right humerus and radius (ulna ?), the interclavicle, the left clavicle, a single vertebral centrum with portions of others, and traces of the scutellæ. These remains are so intermingled with the remains of plants that it has been quite difficult to distinguish bone impression from that of plants. This, however, has been done by whitening the fossils with ammonium chloride, when the texture of the fossils serves to distinguish the one from the other. Parts of the plants have been converted into and destroyed by galena and kaolin, as have also parts of the bones, so that the task has been doubly difficult. There can be no doubt, however, that the observations recorded below are correct. The position of the arm in relation to the pectoral girdle and the position of the girdle in relation to the skull impression first called attention to the possible presence of a fossil amphibian.

There is little to be said of the skull. It is merely an impression in the nodule. It is triangular in form with the snout an acute angle. The angle is, however, exaggerated by the compression to which the fossil has been subjected. The right side of the skull lies over a portion of some plant. The animal is preserved on its back, so that this gives a good opportunity for the study of the pectoral girdle, which is partially preserved. The interclavicle is very large, and from that character the species has been given its name (thoracatus = armed with a breast plate). The interclavicle is an exaggerated "T" with the stem very short. Its anterior margin is curved and ends is a rather sharp, elongate point. The posterior spine is quite short and sharp-pointed, having a length of four millimeters. The interclavicle recalls, in a measure, the same element of *Branchiosaurus*, although it is much more expanded anteriorly and has a shorter spine. In these respects it resembles more nearly a reptilian element. The bone is quite smooth.

The clavicle is of the simple triangular form so characteristic of the Microsauria. It is somewhat displaced backward and its inner margin is slightly obscured.

The humerus is elongate, apparently cylindrical, and has expanded ends. It resembles closely the humerus of *Amphibamus grandiceps*, although its proportions are much greater than in that species. Its length is almost equal to the length of the skull, while in *A. grandiceps* the length of the humerus is only one-half that of the skull.

The radius (ulna ?) resembles in its general proportions those of the humerus. It is a more slender, lighter bone. The impression of the other bone of the fore arm is obscured.

A portion of a single vertebral centrum is preserved. It is from the posterior part of the dorsal series. The centrum is apparently amphicœlous. Its height is about one-half greater than its length. The neural spine is obscured.

The species *Amphibamus thoracatus* Moodie has been described in the Proceedings of the U. S. National Museum, volume 40, page 431, figure 2, 1911.

MEASUREMENTS OF THE TYPE OF AMPHIBAMUS THORACATUS MOODIE.
(Cat. No. 4306, U. S. N. M)

	mm.
Length of entire specimen as preserved	60
Length of skull impression	18
Greatest width of skull impression	15.5
Long diameter of right orbit	4
Transverse diameter of right orbit	3
Transverse width of interclavicle	14
Long diameter of interclavicle	7
Long diameter of clavicle	9
Greatest transverse diameter	3
Length of humerus	10
Greatest diameter of humerus	4
Least diameter of humerus	1.5
Length or radius (ulna ?)	11
Length of vertebral centrum	2
Width of vertebral centrum	3

Genus CEPHALERPETON, new genus.

This genus is founded on remains of an incomplete individual of a relatively large microsaurian from the Mazon Creek shales. The genus is most immediately related to the family Amphibamidæ, of which two species are known. The present form differs from these species in many respects, notably in size. The skull in the present genus is nearly as long as half the entire body of *Amphibamus grandiceps*, inclusive of the tail. Other structural differences are the anisodont teeth, the large size and more median position of the orbits, and the absence of the posterior tympanic notch in *Cephalerpeton.* The form of the skull recalls that of *Melanerpeton* and *Pelosaurus* of Europe, but they are both branchiosaurians, while the present form, from the structure of the vertebræ and the long, curved ribs, is an undoubted microsaurian. Nothing like it occurs in the Kilkenny, Ireland, fauna described by Huxley, and it is totally different in structure from any of the Linton or Cannelton genera, and its like is not known among the forms from the continent of Europe. It is most nearly approached in certain respects by the various species of *Erpetosaurus,* but from this genus it can be readily distinguished by the smooth skull bones, the absence of a posterior table to the skull, and the presence of a highly developed ventral armature. The interorbital width is less than the transverse diameter of the orbit.

The generic characters are found in the broad skull, the anisodont teeth, the median position of the orbits, the absence of a tympanic notch or posterior table to the skull, the presence of sclerotic plates, the great length of the fore limb and the well-developed ventral armature.

Cephalerpeton ventriarmatum new species.

(Plate 1, fig. 4; plate 7, fig. 2.)

The remains on which the present discussion is based consist of an almost entire skull, twenty-six consecutive vertebræ, both fore limbs, twenty ribs preserved on the right side of the vertebral column, and a portion of the ventral armature:

The skull is very broad posteriorly, its width being one-third greater than its length, with due allowance for crushing. A pineal foramen is not preserved. The sutures bounding the premaxillæ, the maxillæ, the nasals, the prefrontals, the frontals, a portion of the parietals, the squamosal, the supratemporal, the quadratojugal and the quadrate (?) are fairly well preserved. The arrangement of these elements can be discerned by reference to figure 2, plate 7. The prefrontals are unusually large and are triangular in shape. The supratemporal is also quite large. The epiotics and the supraoccipitals are not preserved. The surface of the skull bones is smooth and there is nowhere an indication of sculpture.

Portions of four sclerotic plates are preserved in the right orbit. These measure one-half by three-quarters millimeters. The orbits are large and the interorbital space is less than the transverse diameter of the orbit. Thirteen teeth are preserved on the left maxilla. The teeth are apparently pleurodont. They are short, sharply pointed, smooth and unequal. The first two left maxillary teeth from the anterior end are short. Then follows a tooth which is one-third longer than these two. The fourth tooth is somewhat shorter than the third. The fifth and sixth are still shorter and are practically equal. The seventh, eighth and ninth are all large. The ninth is the largest and the diameter of the base is greater than the third. The last four teeth are practically equal in size, though somewhat larger than the first two.

The right mandible is preserved almost entire, though so badly eroded that little can be said of its structure. Impressions of twelve teeth are present on the mandible, and all are apparently equal. The cotylus seems to have been far posterior and an angle of the mandible projected slightly back of the skull.

There remain only a few indefinite impressions of the cervical vertebræ. The union of the skull with the vertebral column is obscured and lost. Impressions of the dorsal vertebræ are well preserved. Wax molds made from these impressions show the structure of the dorsal vertebræ surprisingly well. The vertebræ are long and cylindrical, with the median portions slightly constricted by a deep pit on each side of the low neural ridge, which takes the form observed in *Thyrsidium, Molgophis, Phlegethontia, Dolichosoma* and other genera. The vertebræ are strongly amphicœlous and the notochord was probably persistent. The sides of the vertebræ are smooth.

The ribs are all intercentral in position, agreeing in this respect with all other Carboniferous Microsauria so far studied. The anterior ribs are very broad near the base and recall the broadly expanded ribs described by Schwarz for *Scincosaurus, Ptyonius, Thyrsidium* and other genera. Posteriorly the ribs become slender and cylindrical. They are all rather long and distinctly curved, with probably a cartilaginous tip.

There is preserved a single element of the right side of the pectoral girdle. This is, I think, the coracoid, an element which has hitherto escaped observation among the American Microsauria. It is long, and spatulate at both ends. Its median portion was apparently almost cylindrical. Its form is not unlike that described by Credner for the coracoid of *Branchiosaurus*, save that the lower end of the branchiosaurian coracoid is acuminate. In the present genus it is spatulate. Its relations with other elements of the pectoral girdle have never been satisfactorily determined.

The fore limbs are both partially preserved. The humerus of the right side is complete. It is greatly elongate for a microsaurian. The form of the element is not unlike that of a lizard. The lower end of the bone is spatulate. Endochondrium seems to have been well developed. Very little difference can be seen between the forms of the arm bones which represent the radius and ulna. They are both elongate, with constricted median portion and expanded truncate ends. The carpus is unossified and the cartilage has left no impression on the stone.

The right hand has two metacarpals preserved, which are fully one-half as long as the radius and ulna. They are separated some little distance from the ends of these elements. This may be due to post-mortem shifting, though the carpus was undoubtedly broad. On the left side are preserved a portion of the humerus, the radius and the ulna, with three metacarpals lying next to the vertebral column. The carpal space is not so large on the left as on the right side. The ventral armature is well preserved in a narrow patch about one inch in length. The chevron-shaped rods are quite large, there being two of them in one millimeter.

The type specimen is No. 796 of Yale University Museum. Collected in 1871, at Mazon Creek, Illinois.

MEASUREMENTS OF THE TYPE OF CEPHALERPETON VENTRIARMATUM MOODIE.

	mm.
Entire length of fossil	98
Length of skull	22
Width across base of skull	28
Long diameter of the eye	10.5
Transverse diameter of the eye	8
Interorbital space	4
Length of mandible	26
Depth of mandible at the coronoidal region	3.5
Depth of dentary	2
Length of a long tooth	2
Diameter of long tooth at base	.5
Length of vertebral column preserved	64
Length of a centrum	3
Median width of centrum	1.5
Length of rib	6.5
Width of rib at base	.33
Length of coracoid	8
Width of coracoid at anterior end	2.5
Length of humerus	18
Width of shaft	1
Distal width of humerus	4
Length of radius or ulna	10.5
Width across proximal ends of ulna and radius	3
Length of carpal space	5
Length of metacarpal	6
Length of ventral armature preserved	24
Number of rods in a length of 5 mm	10

Genus ERPETOBRACHIUM, new genus.

The remains on which the discussion of the present genus is based are contained in a rounded nodule, with obverse, from the Mazon Creek shales, some three and one-half inches in diameter. The matrix is the usual reddish ironstone of the nodules contained in these beds, and the bones have been replaced by kaolin. The parts preserved are the scapula, clavicle, portion of the coracoid, the humerus, the ulna and radius, all of the right side of the body.

The generic characters are apparent in the greatly elongated fore limb, in the exceptionally broad scapula, the long radius and ulna, which almost equal the humerus in length—a character hitherto unknown among Carboniferous Amphibia.

Erpetobrachium mazonensis new species.

(Plate 2, fig. 2; plate 8, fig. 3.)

The scapula of the present form is exceptional in its shape. It resembles an asymmetrical pyramid, the anterior side of the lower edge of the bone being contracted so that the anterior edge is arcuate. Its top is very thin, and possibly terminated in a broad cartilage. The lower end is thick and heavy, and the articular surface is apparently well formed, though somewhat obscured.

The element identified as clavicle is lying on its edge and has the proportions of the clavicle of *Mazonerpeton costatum.* The exterior end is somewhat rounded and small. A portion of another element, which I suppose to represent the coracoid, lies alongside the humerus. Its form is quite obscured.

The humerus has a remarkably well-formed head. Its perfection of formation corresponds well with that of the higher reptiles. Its surface can even be divided into an anterior and posterior articulation. It projects posteriorly for the distance of one millimeter from the surface of the shaft. The shaft immediately below the head is somewhat flattened and has an ovoid section. Further on it becomes more flattened, a part of which is probably due to pressure during fossilization. The distal end is somewhat obscured.

The elements of the fore arm are both preserved, and ar approximately equal in size. They are remarkable in tha they exceed or at least equal the humerus in length, althoug they are not so heavy as that element. They are greatl elongate and slender, with the middle of the shaft only moderately contracted. The articular surfaces are well formed, and both bones were hollow, as was also, apparently, the humerus. The ulna is taken to be represented by the most posterior of the two elements, though the relations of the elements may have been reversed.

The base of the left wing of an orthopterous insect, possibly allied to *Paolia gurleyi* Scudder, lies between the radius and the ulna. The nodule also contains impressions of plants, a portion of a frond of a *Neuropteris*, and the impression of one of the *Cordaites*. Lying next the radius is a slender, elongate element, which may be a rib or a portion of a metacarpal. If a rib it indicates that the animal belongs among the Branchiosauria. The fragment is only one-half as long as the radius and is entirely too obscure to base any conclusions upon. The other characters of the specimen point quite strongly to its microsaurian affinities.

The structure of the articular surfaces of the limb bones alone would indicate the microsaurian relationship of *Erpetobrachium*. It may be provisionally associated in the family Molgophidæ with such forms as *Molgophis brevicostatus* Cope, *Molgophis (Pleuroptyx) clavatus* Cope, and *Molgophis macrurus* Cope, from the Coal Measures of Linton, Ohio.

MEASUREMENTS OF THE TYPE OF ERPETOBRACHIUM MAZONENSIS MOODIE

	mm.
Length of scapula	14
Distal width	6
Proximal diameter	3
Length of clavicle (?)	24
Length of humerus	25
Length of ulna	24
Proximal width	4
Diameter of the shaft	2
Distal width	3
Length of radius	25
Proximal width	4
Diameter of the shaft	3
Width of distal end	4

The type specimen is 799 (222) of Yale University Museum. Collected at Mazon Creek, Grundy county, Illinois.

Genus SPONDYLERPETON, new genus.

The specimen on which the genus is founded consists of nine imperfect vertebræ, from the caudal region, inclosed in a brown ironstone nodule from the Mazon Creek shales.

There have been, up to the present, but two *Carboniferous* genera of the embolomerous Stegocephala described. These are *Cricotus* from Illinois, Kansas and Texas, and *Diplospondylus* from Bohemia. Four, possibly five, species have been assigned to *Cricotus* and a single species to *Diplospondylus* (Fritsch, Fauna der Gaskohle, Bd. 2, Tafln 50, 52, 53). It is with considerable interest that the writer is able to add yet another form to the list of known Embolomeri by the description of the largest form of the Mazon Creek amphibian fauna. The present form exceeds *Diplospondylus* by twice its size and is about two-thirds the size of *Cricotus heteroclitus* Cope.

It differs in several important characters from the two genera above mentioned, but is for the present to be located in the same family, the Cricotidæ of the suborder Embolomeri and the order Temnospondylia.

The present form is distinct generically from any form which have been described. The generic characters are found in the form of the vertebral centrum and in the enlarged intercentra. The present vertebræ are twice as high as wide, differing thus from *Cricotus,* in which the centra are practically circular. A character which is of great importance is the large size of the intercentrum, which almost equals the pleurocentrum in size. It is similar to the pleurocentrum in structure, except for the attached neurocentrum and chevron. The present form differs from *Diplospondylus* in the greater length of the intercentrum and pleurocentrum, in the greater size, in the larger proportions of the neurocentrum and the greater proportionate size of the intercentra.

Spondylerpeton spinatum new species.

(Plate 8, figs. 1 and 2; plate 9, fig 1)

The species is very imperfectly known. Sufficient is present, however, to show its wide generic differences from other forms of the Cricotoidæ. These characters are of a phylogenetic nature, and indicate the more primitive nature of the present form, as we would expect from its geological position. The sutures separating the four vertebral elements are clearly apparent. The pleurocentral-neurocentral suture is apparent in four vertebræ.

There is but a single pleurocentrum preserved complete. This shows the form of the attached neurocentrum and chevron, which corresponds to the hypocentrum pleurale, according to Fritsch. These structures are shown in the drawing, figure 1, plate 9. The pleurocentrum is flattened laterally, with a rather large canal for the notochord. Its sides are marked with four longitudinal grooves. Surfaces for the attachment of ribs are not present, and for this reason, as well as the presence of chevrons, the vertebræ are supposed to be caudals. As such, they represent an animal of some three or four feet in length. It was the giant of the Mazon Creek Amphibia.

Attached to the upper side of the pleurocentrum by a sutural union occurs the neurocentrum. The neural arch is quite large and is oval in outline, although somewhat constricted at the tip. The spine of the neurocentrum is rather long and broad at its base, measuring 12 mm. across the anterior zygapophysis. The nerocentrum is laterally flattened and ends in a rather acute and somewhat rugose point. It was probably tipped with cartilage. The anterior zygapophysis occurs well down on the neurocentrum; its lower edge being five millimeters from the suture separating the pleurocentrum and the neurocentrum. The posterior zygapophysis occurs quite high up on the neurocentrum, and lies at a distance of 15 mm. from the pleuro-neurocentral suture, thus indicating an extreme posterior inclination of the neural spine. The posterior zygapophysis of the best-preserved vertebra is separated from its mate, the anterior zygapophysis, on the next succeeding vertebra, by a space of five millimeters.

The ventral surface of the pleurocentrum bears a structure which is without doubt a chevron, although the character of the opening can not be determined. It is elongated and is united by a broad base to the pleurocentrum. Its union is by a clearly defined suture, which is apparent on three vertebræ. The condition represented by the specimen represents almost exactly the condition figured by Cope for the caudal region of *Cricotus crassidiscus* Cope[1].

The intercentrum of the present form is fully as large as the pleurocentrum. The significance of this has already been mentioned. There is no difference, except for the attached neurocentrum and chevron, in the form of the intercentrum and the pleurocentrum. Its body is pierced by the large notochordal canal.

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[1] Cope, E. D., 1890. Trans. Amer. Phil. Soc., vol. xvi, p. 246.

The condition of the vertebral structures represented by the above-described form is so essentially similar to that of *Cricotus*, which has been fully described by Cope, that nothing new can be added to the phylogenetic relations of the separate pieces of the vertebral column. It is remarkable that such a type should be found so low in the geological scale, but it is not unexpected, since we must, without doubt, look to the early Devonian or late Silurian for the earliest types of the Amphibia, which are yet unknown, although they have left their footprints in the rocks of the Devonian and Mississippian epochs of this country and a single skeleton in the Subcarboniferous of Scotland. That our knowledge of the amphibian fauna of the Carboniferous is woefully incomplete is attested by the fact that nearly every specimen collected represents a type distinct from any hitherto known. Such is eminently true of the collection which has just been described. The characters on which the genera and species are based are apparently ones of value, for they have stood the test of time in other groups.

MEASUREMENTS OF THE TYPE OF SPONDYLERPETON SPINATUM MOODIE.

(No. 793 (26) and obverse, Yale University Museum.)

	mm.
Length of specimen	60
Length of pleurocentrum	11.5
Height of pleurocentrum to base of neurocentrum,	20
Length of neurocentrum	33
Width of neurocentrum at base	9
Width across anterior zygapophysis	12
Width across posterior zygapophysis	10
Length of intercentrum	10
Height of intercentrum	10.5
Height of chevron	3
Length of chevron	18
Width of notochordal opening	5
Height of notochordal opening	4.5
Height of neural canal	12
Greatest width of neural canal	6

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THE KANSAS UNIVERSITY
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KRAMERIA CANESCENS GRAY.

BY CHARLES M. STERLING.

(Plates 15-22.)

KRAMERIA CANESCENS inhabits the arid regions of southwestern North America. It occurs on the mesa and low hills as scattered individuals; rarely are several of them growing together in groups. The species was reported by Doctor Merriam, in his account of the Death Valley expedition, as common in the dry parts of the valleys of the Muddy and Virgin rivers in southern Nevada. Dr. J. M. Coulter speaks of it, in his Manual of Phanerogams and Pteridophytes of Western Texas, as common in southern and western Texas; and it is said to be particularly abundant along the Rio Grande, where the natives use an infusion of the bark of the roots to dye leather brownish red.

Part of the material for this investigation was collected on Tumamoc Hill, Tucson, Ariz., in July, 1908, by Mr. L. M. Peace; and in October, 1909, The Desert Botanical Laboratory, through the kindness of Doctor MacDougal, furnished additional material for the study of the roots.

The irregular flowers of *Krameria* have made its classification somewhat uncertain. It has often been included in the Polygalæ, but its close relationship to *Cassia* indicates that it should be included in the Leguminosæ or Cæsalpinaceæ. Chodat has placed it in a separate family, the Krameriaceæ, which includes but the single genus *Krameria*, embracing thirteen species, growing in the warmer parts of North America, and in South America as far south as Chile.

Krameria canescens is a low shrub, which attains a height of about 50 cm. The hard, woody stems are usually much branched. The branches may spring from the primitive stem or the bases of other branches which have died down. (Fig. 2, plate I.) During seasons of excessive drouth the stems may be without leaves, but under favorable conditions they are provided with small, narrow leaves. The specimens used for this investigation, collected in the rainy season of 1908, show the stem and branches well supplied with leaves. (Fig. 1, plate I.) Both young stems and leaves are covered by a dense coating of closely appressed trichomes. Many of the branches have been modified as spines, thus reducing the surface for evaporation. The root attains a very great length and thickness in comparison to the low growth of the shrub. This condition corresponds well with the dry climate and scant water supply of the earth in its habitat. The thick main root produces many secondary roots, which have but few branches.

The resemblance of *Krameria canescens* to the South American species of *Krameria*, yielding the official drug, makes it worthy of a somewhat detailed investigation.

A comparison of the tissues of *Krameria canescens* with those of the official South American species shows its close relationship to the species found growing in the northern part of South America and on the adjacent islands. This relationship is also shown by the structure of the flowers in which *Krameria canescens* and those species confined to the northern parts of South America have four stamens and three fully developed petals, while the one species, *Krameria triandra*, growing farther south, has three stamens and two fully developed petals.

THE STEM.

The exceedingly hard, woody stem of *Krameria canescens*, although not presenting any anomalous structures, has several interesting characteristics. The young stems are protected by a cutinized epidermis, which apparently remains functional for a period of three to five yars, and is then replaced by cork. A primary cortex and pericycle, not sharply differentiated, surround the vascular bundles, which form a hollow cylinder enclosing the medulla. (Fig. 3, plate II.)

The epidermis, consisting of a single layer of nearly isodiametric cells, 24 microns in radial diameter, with a cuticle 8 microns in thickness, is in no way unusual (*e*, fig. 3, plate II).

But the dense covering of thick-walled trichomes on its surface provide an excellent means of protection against evaporation. The trichomes are one-celled, with walls strongly cutinized on the lower portions, and are but weakly, or not at all, cutinized on the upper portions. They vary in length from 150 to 600 microns and average 850 on a sq. mm. (*h*, fig. 16, plate IV).

Stomata, which stand at right angles to the long axis of the stem and lie in the same plane with the epidermal cells, appear to be without any of the special protective devices found in desert plants, and are protected only by the numerous closely appressed trichomes (*s*, fig. 16, plate IV). The stomata are uniformly distributed and average 98 on a sq. mm. The cells of the epidermis contain chloroplasts and tannin and have a brownish-red color.

The primary cortex and pericycle are not sharply differentiated, but in the region of the line *d*, fig. 3, plate II, there are numerous parenchyma cells filled with starch. The location of these cells just outside of a zone of tissue containing many bast fibers would indicate that they form the inner boundary of the primary cortex. The primary cortex is made up of a compact palisade and isodiametric or radially elongated parenchyma cells (fig. 15, plate IV). The palisade seldom contains more than one row of cells, which are closely fitted together, and have relatively small intercellular spaces between them. Radially, they measure 30 to 48 mm. in diameter and contain an average of 120 chloroplasts (*cl*, fig. 17, plate IV). The chloroplasts are biconvex and disc-shaped, 4 to 5 microns in diameter and 1 to 1.75 microns in thickness. The rest of the primary cortex is made up on thin-walled parenchyma cells, most of which contain chloroplasts, although many are almost completely filled by large rosette-aggregate crystals of calcium oxalate, while others filled with starch grains are not uncommon. Radially they measure from 25 to 45 microns.

Surrounded by the primary cortex is a pericycle consisting of thin-walled parenchyma cells, and angular, rather strongly lignified bast fibers (fig. 6, plate II). The long, slender bast fibers occur either singly or in groups, and by means of their long, tapering ends are spliced together, forming a tissue well suited for strengthening. They have a few very small straight pits. In length they vary from 850 to 2050 microns and in width from 12 to 18 microns. The parenchyma cells of the pericycle are similar in form and structure to those of the primary cortex. For the most part they contain starch, but in a few may be found chloroplasts, and in many crystals of calcium oxalate. In the palisade and all of the parenchyma cells of both primary cortex and pericycle there are large quantities of tannin, and all have a brownish-red color.

The narrow vascular bundles are collateral, and are separated by narrow medullary rays, one cell in width.

The phloëm is composed of undivided mother cells of sieve tubes and companion cells and thin-walled parenchyma, interspersed with comparatively thick-walled, lignified bast fibers (fig. 10, plate III). The bast fibers are similar in structure and arrangement to those of the pericycle, but a greater proportion of them occur singly, and the groups are smaller. The vertically elongated parenchyma cells contain starch, amorphous proteids, and crystals of calcium oxalate (fig. 11, plate III). Sieve tubes with well-developed sieve plates were not found, but the stems are well supplied with undivided mother cells, which are filled with granular proteid matter, and together with the parenchyma contain tannin in considerable quantities (*n*, fig. 11, plate III).

The elements making up the xylem are fiber tracheids, water tubes, and few wood parenchyma cells. The most conspicuous of these is furnished by the fiber tracheids, which are thick-walled, strongly lignified and compactly arranged, thus leaving very small intercellular spaces. They are cylindrical, and have long, tapering ends, which overlap and are interwoven to make the wood exceedingly strong (fig. 12, plate III). They vary in length from 350 to 1100 microns and 10 to 14 microns in width. Although the thick-walled tracheids are perforated by numerous bordered pores, and are thus well adapted for water conduction, the numerous water tubes are apparently sufficient to perform that function and leave the tracheids to serve rather the function of water storage. (See fig. 8, plate III.) In a stem 4.21 mm. in diameter, the tracheids comprise an area of 5.9 sq. mm., which is equal to 78 per cent of the xylem or 19.7 per cent of the whole stem. The small cavities of the tracheids have a total area of 0.7 sq. mm., which is equal to 8.75 per cent of the xylem or 3.5 per cent of the whole stem.

The tracheal elements are composed of water tubes having spiral and reticulate thickenings and those having bordered pits. Next to the medulla, and formed in the protoxylem, lie the small spiral tubes, while adjacent to them are the somewhat larger reticulate tubes (fig. 9, plate III). But throughout all of the rest of the xylem only tubes with bordered pits are to be found. They have lignified walls 1.5 to 3 microns in thickness, and average about 30 microns in diameter. Although they occupy a much smaller area of the xylem than the tracheids, the water tubes have relatively much greater water-carrying capacity, the total, for the stem given above, being 14.5 per cent of the xylem or 6 per cent of the whole stem.

The tissues of the xylem are not distributed in such a manner as accurately to indicate the periods of growth. However, as the larger water tubes are in rather loosely formed rows, concentrically arranged, and frequently accompanied by rows of wood parenchyma, they appear to form the boundary lines of the periods of growth. The wood parenchyma cells are developed prior to the larger water tubes, thus indicating that the wood parenchyma cells are formed at the end of one growing season and the larger water tubes at the beginning of the season following. The vertically elongated cells contain many circular straight pits (figs. 22 and 23, plate V); and as they are abundantly supplied with starch, they furnish additional evidence that the wood parenchyma is formed at the end of the season's growth for the storage of reserve materials.

Separating the vascular bundles are the numerous narrow medullary rays, usually consisting of a single row of cells. In the xylem portion the walls are relatively thin, lignified in the older part only, and contain numerous straight, circular pits. They are from three to six cells in height, and vertically elongated (figs. 20 and 21, plate V). Frequently the tracheids crowd in upon the medullary ray cells and cause a thickening of their tangential walls (fig. 5, plate II). The cells of the phloëm portions have cellulose walls, and as the outer ones are tangentially stretched the rays become wedge-shaped. In all parts the cells are well supplied with starch—a fact which, taken in connection with their structure, indicates that their chief function is that of storage.

At the center of the stem, surrounded by the vascular bundles, is a rather large medulla. The cells have lignified, pitted walls. Those composing the central part are nearly isodiametric (fig. 25, plate V), while the marginal cells are somewhat narrower and vertically elongated (fig. 9, plate II).

All of these cells are well adapted for storage, and many are packed with well-formed starch grains while others contain large crystals of calcium oxalate. Tannin is abundant throughout the medulla.

THE ROOT.

In making this investigation, roots young enough to show primary structures were not obtainable, and as in all specimens the main root was too large to section and illustrate as a whole, it was necessary to select secondary roots for study. These, however, were found to have their tissues in structure and arrangement almost identical with those of the main root. In transverse section, a root shows a broad bark surrounding a circular xylem (fig. 4, plate II).

The brownish-red cork is developed in regular radial rows, and becomes scaly and dark brown on the exterior (figs. 30 and 35, plate VI). Lying between the phloëm and phellogen is a broad zone of parenchyma cells interspersed with bast fibers (fig. 4, plate II). These fibers are similar to those of the stem, but differ in being shorter, slightly broader, and more irregular in form. They vary from 8 to 20 microns in breadth and from 400 to 1050 microns in length.

The medullary rays and wood parenchyma of the root resemble in every way the corresponding tissues of the stem; but in the root the cells are uniformly larger.

The phloëm corresponds in structure to that of the stems (fig. 30, plate VI). However, there is a difference in the distribution of the bast fibers. In the phloëm of the root the fibers occur in larger groups than in the zone of parenchyma adjacent (fig. 30, plate VI), while in the stem the larger groups of fibers are found outside the phloëm in the pericycle. In the thin-walled parenchyma cells throughout the bark there are large quantities of starch, and crystals of calcium oxalate. The cells have a yellowish-red color, and in all of them tannin is abundant.

The elements composing the root xylem are the same as those found in the stem. The fiber tracheids, varying in length from 200 to 600 microns, are shorter and more irregular in form than are the stem tracheids (figs. 32, 33 and 34, plate VI). Frequently the root trahceids have blunt or irregularly shaped ends (fig. 32, plate VI). The most striking difference between the stem and root is found in the conspicuously large and numerous water tubes of the root xylem (fig. 30, plate VI). Excepting the tubes of the protoxylem, all of the water tubes in roots have bordered pores, which are oblong and lie horizontally in the thick, lignified walls (fig. 31, plate VI). The water tubes vary from 12 to 65 microns in diameter, and have walls from 1.5 to 3 microns in thickness. In a root 4.84 mm. in diameter the area of water-tube cavity amounts to 31 per cent of the xylem or 6.8 per cent of the whole root. The total area of tracheid cavity amounts to 6.7 per cent of the xylem or 1.3 per cent of the whole root. Combining these amounts gives a total for both water tubes and tracheids of 37.7 per cent of the xylem, or 8.1 per cent of the whole root, devoted to the carrying and storage of water. Comparing this data with that given above for a stem 4.21 mm. in diameter, and having a total capacity for both water tubes and tracheids amounting to 23.25 per cent of the xylem, or 8.75 per cent of the whole stem, shows that as a whole the stem has the greater capacity for holding water.

THE LEAF.

The small, narrow, simple leaves are developed in seasons favorable for growth, but in seasons of excessive drought they may be entirely wanting. They are bifacial and have the stomata standing longitudinally at right angles to their long axes (figs. 39 and 40, plate VIII). The stomata, averaging 95 on a square millimeter, lie in the same plane with the cells of the epidermis (fig. 42, plate VIII).

The epidermis, closely resembling that of the stems, bears numerous unicellular trichomes, which give to the leaves a fine silky appearance (fig. 47, plate VIII). The trichomes are usually bent near the base, so that they lie close to the surface and make a thick covering over the entire leaf surface. They vary in length from 150 to 600 microns, and, like the trichomes of the stem, are thick-walled and have the lower portions cutinized, while the upper portions are but weakly, or not at all, cutinized. Although the trichomes on the leaves are very numerous, averaging 450 to 500 on a square millimeter, the number is exceeded by the stems, which bear an average of 850 on a square millimeter.

Lying beneath the epidermis, and extending around the entire leaf, is the palisade tissue, usually consisting of a single layer of cells (fig. 38, plate VII). The cells well supplied with chloroplasts are cylindrical in tangential section, and lie relatively close together (fig. 41, plate VIII). The rest of the mesophyll is made up of parenchyma cells, which, lying close together, thus give but little intercellular space in the leaves (fig. 38, plate VII). No regularly arranged border parenchyma surrounds the vascular bundles.

The very conspicuous water-carrying system is composed entirely of tracheids, which for the most part have bordered pores (fig. 28, plate V) ; but in the basal portion of the midvein spiral tracheids may be found (fig. 46, plate VIII). The ultimate ends of the veins are composed of large groups of nearly isodiametric tracheids with numerous bordered pores (fig. 27, plate V, and figs. 44 and 45, plate VIII). The enormous number of tracheids furnish adequate capacity for the storage of a large water supply in the leaf. Interspersed with the tracheids are many thin-walled parenchyma cells (fig. 28, plate V, and fig. 43, plate VIII).

The phloëm consists of undivided mother cells, cambiform cells, and parenchyma (fig. 29, plate V). All of these cells have walls of cellulose and are filled with granular proteid matter. The phloëm occupies but a relatively small portion of the bundles, and in no case were well-formed sieve tubes found.

THE CHLOROPLASTS.

Chloroplasts are present in both leaves and stems. In leaves they occur in the epidermis, palisade, and nearly all of the parenchyma of the mesophyll, while in stems they occur in the epidermis, palisade and greater part of the primary cortex, and even in the outer part of the pericycle. Numerically they are about equally distributed in the corresponding tissues of stem and leaf, an average of 128 being present in a leaf palisade cell and about 50 in a parenchyma cell of the stem. In form they are circular and biconvex, varying from 4 to 5 microns in diameter and 1.25 to 1.75 microns in thickness.

STARCH.

Both stems and roots are provided with an abundant supply of starch. The spherical, oblong or ovoid grains are simple, or 2, 3, 4 and 5 compound. In the stem they are located principally in the pericycle, medullary rays, and medulla, but they may also be found in a few of the parenchyma cells of the primary cortex and in the phloëm and wood parenchyma. They vary in size from 4 to 18 microns (fig. 49, plate VIII). Although the root starch closely resembles that of the stem in form and structure, the grains are uniformly larger and more oblong in shape (fig. 48, plate VIII). They range in size from 10 to 40 microns and are very abundant in the parenchyma of all parts of the bark, medullary rays, and wood.

CRYSTALS.

Crystals of calcium oxalate are present in all parts of the plant. They are monoclinic prisms, or rosette-aggregate in form, and vary in size from 2 to 40 microns in diameter. Aggregate crystals 10 to 30 microns in diameter are abundant in the leaf parenchyma, while the small monoclinic prisms, 2 to 10 mm. in diameter, are relatively few in number (*b*, fig. 51, plate VIII). In the stem, rosette-aggregates occur commonly in the parenchyma of the primary cortex and medulla (*a*, figs. 51 and 52, plate VIII), while in the phloëm they are seldom found, but monoclinic prisms are very abundant (fig. 53, plate VIII). The stem crystals are slightly larger than those of the leaf, and in the root they are considerably larger than in any other part of the plant. In the parenchyma cells of the outer root bark large aggregate crystals are found in considerable numbers, and in inner parenchyma, especially those cells adjacent to the bast fibers, are densely packed with monoclinic prisms (fig. 50, plate VIII).

All parts of the plant are well supplied with tannin, and it is especially abundant in the bark of both roots and stems. Excepting the conducting cells of the xylem and phloëm, all parts of the plant are intensely colored, from a reddish brown in the outer cork to a yellowish red in the inner parenchyma of the bark. The color is very persistent, and in order to make a detailed study of the tissues it was necessary to decolorize the material. This could be accomplished only by long bleaching of leaves and root and stem sections in aqueous solution of potassium hydrate and chloral hydrate.

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CONTENTS:

EVIDENCE OF PLEISTOCENE CRUSTAL MOVEMENTS IN THE MISSISSIPPI VALLEY, ... J. E. Todd.

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EVIDENCE OF PLEISTOCENE CRUSTAL MOVEMENTS IN THE MISSISSIPPI VALLEY.

BY J. E. TODD.

IT has been thought worth while to call attention to the facts bearing on this subject which have been brought out by a recent study of glacial deposits in Kansas. The more novel facts are (*a*) the strong westerly trend of glacial movements during the Kansan epoch, and (*b*) the high altitude attained on the west compared with corresponding levels farther east.

First. The westerly trend is shown (*a*) by the fact that the ice lobe did not reach to the Kansas river in Douglas county, at least not so as to affect its channel, while from near Lecompton to Wamego there is abundant evidence of its filling the preglacial channel and pushing south of it several miles, especially in Shawnee and Wabaunsee counties. The Kansas river was dammed southwest of Wamego, so that its level stood 200 feet above the present stream. This is shown by a boulder-lined outlet connecting with another valley southeast. Similarly a lake was formed in Mission creek valley, west of Topeka, from which boulder-marked channels lead over into the Wakarusa valley on the south.

(*b*) This is shown also by glacial striæ, especially those of higher levels, which record the main movements of the ice sheet. There are also others, particularly those at lower levels, which conform to the direction of the valleys in which they are found, as though formed when the ice sheet was thin and weak. The general movement is shown by the following table of striæ:

Locality, observer, reference.	*Direction.*
Near Omaha, six or eight feet above the river C. A. White—Geol. Ia., vol. I, p. 95.	S. 51° W.
Near mouth of Platte river Meek—Final Rept. Neb., p. 92	S. 20° W.
Two miles east of Pacific Junction, Iowa J. A. Udden—Geol. Ia., vol. 13, p. 177.	S. 12° and 14° W.
Three miles south of Pacific Junction, Iowa J. A. Udden—Geol. Ia., vol 13, p. 177.	S 25°, 29° and 34° W.
Three miles east by north from Tabor, Iowa J. A. Udden—Geol. Ia., vol 13, p. 177.	SW.
One-half mile south of Hinton, Iowa J. A. Udden—Geol. Ia., vol. 13, p. 177.	S 7° and 50° W.
One mile north of Macedonia, Iowa. J. A. Udden—Geol Ia, vol. 11, p 269	S. 2° W. and S. 10° E.
Three to four miles south of Pacific Junction, Iowa J. E. Todd—Bull. U. S. G. S. 158, p. 69.	S 9°, 40° E.
South of Plattsmouth, Neb., 40 ft. above river J. E. Todd—Bull. U. S. G. S 158, p. 69	S.-SW.
Bennett, Neb. J. E. Todd -Bull. U. S. G S. 158, p. 69.	S. 17°, 41°, 61°, 88° W
Weeping Water, Neb E. H. Barbour—Neb Geol. Surv, vol 1, p. 169.	S. 29° W, S. 11° E.
One mile north of St. Joseph, Mo., 125 ft. above river J. E. Todd—Geol Rept Mo, vol. 10, p. 121.	S 26° W.
One mile northeast of Kansas City, 130 ft. above river J. E. Todd—Geol. Rept. Mo., vol. 10, p. 121.	S 7°, 9°, 24° W.
East part Kansas City, 100 ft J. E. Todd—Geol. Rept Mo., vol. 10, p. 122	S. and S. 6° E.
Seneca, Kan. L. C. Wooster—Amer Geologist, vol. 10, p. 131	S. 21° 24° W.

(*c*) The ice sheet entering Kansas was from the Des Moines valley rather than from the James and Missouri valleys. This is shown clearly by the distribution of red quartzite boulders, for they are found very abundantly on the extreme western edge of the ice lobe. If the ice had come down the Dakota-Missouri valley they would have been distributed only to the eastern half of it, and therefore would have been far east of the marginal effects of the ice, for the original ledges extend only a short distance into South Dakota.

Moreover, the red boulders frequently abound in white and red pebbles, such as are not known to occur in the quartzite ledges of South Dakota, but are found farther east in Cottonwood and Rock counties, Minnesota, where the original deposits were nearer the old Archæan shore on the northeast, which furnished the material. There seems no doubt, therefore, that the ice of Kansas in the Kansan epoch passed through the upper part of the main Des Moines river valley.

This conclusion discounts strongly an oft-used map of North America, professing to show the ice streams at the maximum extent of the ice, and we may the more easily admit its inaccuracy when we know the impossibility of a slender ice lobe maintaining itself for 500 miles from Dakota to Kansas along the edge of a dry and probably warm region like the great plains, doubtless traversed then as now by southwest winds.

Second. Another significant fact is that the ice overrode points now over 1500 feet A. T. This was true in northern Pottawatomie county, about Blaine and Wheaton, Kan., where the preglacial surface rises to that height. The surface of drift deposits lies at that altitude at Summerfield in Marshall county, Kansas, and along the divide northward past Virginia and other points in northern Gage county, Nebraska.

This fact should also be contrasted with the fact that the highest points of the limit of the ice on the east side of the same lobe in northeastern Iowa is only about 1200 feet A. T. in Winneshiek, Allamakee and Dubuque counties. It should also be compared with the fact that southeastern Iowa now lies only 750 feet A. T., or only half the height in Kansas.

Taking the altitudes as we now find them, we can not see why, if the ice sheet reached 1500 feet in Pottawatomie county, Kansas, it should not have pushed over the 1300-foot levels in northeastern Iowa and scores of miles farther into the Wisconsin driftless area, and well across Illinois southeast, in which direction there was an open field and lower levels. We may reason it thus: Taking a point in northern Kossuth county, Iowa, as a common point of passage for all points south from Kansas to Illinois, then taking Blaine, Kan., 1500 feet A. T., and assuming an average slope for the surface of ice of 25 feet per mile, we should find the top of the ice sheet over northern Kossuth county to be over 9000 feet A. T. If a similar slope prevailed also southeast to West Union, Iowa, the ice would have reached 5275, or 4000 feet above the height of the present surface there, and in a southeast direction the slope would have carried it beyond Bloomington, Ill. This is also far beyond the observed limit in that direction.

Mr. J. E. Carman, in the Illinois Geological Survey Bulletin 13, represents the limit of the Kansan till reaching nearly to Savannah, Ill., and a little beyond Fulton, Ill.; and Leverett, in the U. S. G. S. Monograph XXXVIII, places the margin through Hancock and Adams counties, and crossing the Mississippi river near Hannibal, Mo. With the slope assumed and the surface as now, the ice should have gone 70 miles farther in that direction.

Now, if ice may be used roughly in this way as a level, as seems reasonable, it affords evidence that since the Kansan epoch there has been a sinking of the Mississippi region, or a rise of the Kansan, or both. That the first is in a measure true seems attested by the fact that the trough of the Mississippi from St. Paul to Quincy, Ill., is 100 to 150 feet deeper than is demanded by the level of the present stream. Professor Calvin called attention to this fact in his paper in the Proceedings of the Iowa Academy of Sciences, volume 14, page 213. Bedrock is from 150 to 220 feet below low water when the depth adequate for the present stream is only 50 or 60 feet.

Another evidence of the same movement is found in the strong easterly trend of the Iowan ice sheet in eastern Iowa as compared with that of the Kansan there.

This, however, is not enough to fully explain the facts. That there has also been a rise of the Kansan side seems probable, not locally, but in the general westward elevation of the plains. Formerly, when the deposits of the plains were thought to be of lacustrine origin, it was common to speak of the Pleistocene elevation of the Rocky Mountains. The Fluviatile theory has relieved the necessity for that view; but may there not have been some movement of that sort?

An argument in favor of this is found in the fact that quite generally along the Kansas streams and the Missouri river in this latitude there is abundant evidence that the drainage was 85 to 100 feet higher than now. The preglacial channel of the Kansas river at Manhattan was about 100 feet higher than that of the present channel. It was a little lower at Topeka, while at Lawrence a terrace of later date is well developed, with numerous boulders at the bottom of alluvium, and its top 80 to 100 feet above the present stream. Glacial striæ around Kansas City are not found below 125 feet above the Missouri, although there are numerous ones above that level. At Weston, Mo., a cobblestone stratum twenty feet thick, containing red quartzite and granite boulders, is found about 150 feet above the present level. (See Missouri Geological Survey, vol. 10, p. 146.) This terrace, due to the recent cutting down of the Missouri river, has been ascribed to the lowering of the channel into the Ozark limestones in central Missouri, but quite as plausibly it may be ascribed to a Post-Kansan elevation of the region. It need hardly be stated that along the Missouri through the Carboniferous rocks, bedrock is rarely more than 50 or 60 feet below low water. In some shaly portions and in the soft Cretaceous sands and clays of the north it is 100 to 125 feet below.

We can conclude, therefore, that the crust was raised at least 100 feet in Kansas, and depressed 100 feet in eastern Iowa and Wisconsin, or a total relative movement of 200 to 600 feet of eastern subsidence since the time of the Kansan ice sheet. May not the less easterly movement of the ice of that time be further accounted for by a more rapid rise of the underlying rock surface on the east and the southeast? May not the southwesterly trend of the low ledges traversing the eastern part of Kansas, with the corresponding direction of the tributaries of eastern streams, have had an appreciable effect, favoring the westerly movement of the ice in that region? May not the greater heating of the western half of the ice lobe, whether from the maximum daily water temperature coming in the afternoon (see Science, new series, vol. 14, pp. 749-1901), or from the warm southwesterly winds, have rendered the west half of the ice sheet more active, and so increased its westerly movement.

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CONTENTS:

THE ACTION OF SALT SOLUTIONS ON STRIPS OF THE FROG'S INTESTINE .... *Grace Russell.*

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THE ACTION OF SALT SOLUTIONS ON STRIPS OF THE FROG'S INTESTINE.

BY GRACE RUSSELL.

(Plate 23.)

(From the Physiological Laboratory of the University of Kansas.)

In this paper are briefly described the effects of salt solutions of various concentrations upon the smooth muscle fibers, especially the longitudinal, in the intestine of the frog.

The effect of salt solutions upon smooth muscle fibers has been studied by many investigators, but the works of McGill,[1] Mathison,[2] Meigs,[3] Stiles,[4] Langley,[5] Menis[6] and Row[7] I believe correspond more closely to my problem than do the works of others that I read.

The method employed was very simple. After the spring frog was pithed, the abdomen was opened, and pieces about one centimeter long were removed from the intestines as required. The segment was flushed with Ringer's solution and attached to a writing lever at one end, properly weighted to secure tonicity of the intestinal strip, and suspended in a glass cylinder, into which the solutions to be tested were carefully placed. The lower end of the segment was attached to a small siphon tube, which drained the fluid.

In each case a record was first secured with the strip in isotonic Ringer solution. This was then siphoned off and replaced by the special salt which was to be studied. In no case was the same strip used twice. It was interesting to note that strips from some frogs when suspended showed peristaltic action, while those from others did not. But as soon as the salts were added the peristaltic movements either decreased or ceased. The period of action of each solution was limited to about eight minutes and was followed in each instance by an isotonic Ringer solution. I did not attempt to determine whether the observed effect of the salt was upon the muscle, contractile tissue or nerve sells or nerve endings.

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[2] Mathison, G. C., 1911, Journal of Physiology, vol. XLII

[3] Meigs, E. B., American Journal of Physiology, vol. XXII, 1908.

[4] Stiles, P. G., 1903, American Journal of Physiology, vol. VIII, No. 4, p 269.

[5] Langley, 1911, Journal of Physiology, vol. XLII, Proceedings, p. XXIV,

[6] Menis, 1911, Journal of Physiology, vol. XLII, p. 326.

[7] Row, R., 1904, Journal of Physiology, vol. XXX.

After many trials an isotonic indifferent Ringer solution was secured, in which the moist strip neither relaxed nor contracted, but continued its peristaltic movements. The following solutions were then employed in the experiments: the influence of, first, slight alkalinity; second, slight acidity of Ringer solutions; third, NaCl in strengths from m/32 to m/8; fourth, KCl from m/64 to m/8; fifth, $CaCl_2$ from m/64 to m/8; sixth, $MgSO_4$ from m/32 to m/8; seventh, $BaCl_2$ from m/64 to m/8. Also, the influence of tap water and double-distilled water were determined.

I might state at once that tap water caused a marked contraction, possibly due to the large percentage of calcium, while double-distilled water had an opposite effect, namely, that of relaxation, probably due to the extraction of salts from the tissues. This corresponds with Meigs' and McGill's results on smooth muscles from the stomach of the frog with hypotonic solutions.

The accompanying plate illustrates characteristic curves from the different solutions and their most pronounced effects.

A neutral Ringer solution was made .04 per cent alkaline by adding Na_2Co_3 to it. In this solution the peristalsis ceased at once, and the contraction reached its height within a half minute. Though the per cent of alkalinity was small, the effect was quite marked, producing contractions in each case.

In a .04 per cent acid Ringer solution, made so by adding HCl, peristalsis ceased at once, and within a half minute reached its limit of relaxation; relaxing seldom to the same extent as the alkaline Ringer contracted. An m/64 to m/32 NaCl produces a prolonged relaxation, whereas an m/32, and in some cases m/8 NaCl, proved indifferent.

In an m/32 and m/16 KCl solution the contraction of the specimen was immediate and rapid and continued for about four minutes, when it gradually relaxed. But it never returned to normal. In m/64 KCl it was often indifferent, and in m/32 KCl slight relaxation took place. An m/8 KCl strength proved toxic.

It is interesting to note that in $CaCl_2$ solutions, after peristalsis ceased the contractions usually began at once, lasting from one to five minutes, and then in most cases the strip gradually returned to its original length. This tendency of contraction and then returning to its original length was most pronounced in m/32 solutions. The above results with NaCl, KCl and $CaCl_2$ agree with those obtained by Stiles.

In $MgSO_4$ solutions, ranging from m/8 to m/32, intestinal strips relaxed, but relaxation was often more pronounced in an m/32 solution. Magnus in one of his papers states that $BaCl_2$ was a strong stimulus to the intestines and always causes a contraction. My results corroborate his statement, as is shown by the curves. The specimens did not reach their original length after the first contraction, and in each case the contractions were very pronounced.

This work was pursued under the guidance of Dr. I. H. Hyde, to whom I am under great obligations for help and advice.

The general conclusion drawn from the study of the above experiments is that the contraction of the intestinal strip of the frog is produced by solutions of $BaCl_2$ from m/64 to m/8; KCl from m/32 to m/16; $CaCl_2$ from m/64 to m/8 and alkaline Ringer solutions; while acid Ringer, NaCl from m/32 to m/8 and $MgSO_4$ from m/32 to m/8, cause relaxation. These results are probably due to the action of the solution on the longitudinal muscle fibers in the frog's intestine.

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CONTENTS:

On a Comparison of Three Skulls: Castoroides ohioensis, Castoroides kansensis, and Castor fiber.......... *H. T. Martin.*

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ON A COMPARISON OF THREE SKULLS: *CASTOROIDES OHIOENSIS, CASTOROIDES KANSENSIS,* AND *CASTOR.*

BY H. T. MARTIN.

(Plates 24-27.)

(Contribution from the Zoölogical Laboratory, No. 199.)

SINCE the first discovery of *Castoroides ohioensis* and its description, in 1838, by Foster, there has been approximately twenty specimens, mostly fragmentary, reported from as many different localities. Out of this number it is interesting to note that only one, that from Dallas, Tex., was found west of the Mississippi valley. This, coupled with the fact that the Boicourt specimen figured in this paper is a new addition to the Pleistocene of Kansas, adds much to the value of the specimen.

Through the courtesy of the secretary of the Smithsonian Institute, the writer has been allowed the privilege of figuring and comparing with our Kansas specimen a nearly complete skull of *Castoroides ohioensis.* So perfect is this specimen that only a small portion of both the malar arches is all that is missing. The skull is beautifully preserved, with the dentition absolutely perfect. The double posterior nares, well shown, is formed by the pterygoides being laterally compressed at about their middle, until they meet, thus forming two orifices instead of one, as in all other rodents. The superior fossa, pyriform in shape, the lower and smaller one triangular. (See plate 25, fig. *A,* at *a-a.*)

It is unfortunate that so little is known of the history relating to the discovery of the beautiful skull which the writer has been very kindly allowed to figure along with the Kansas specimen. The only data that seems to be attached to the specimen is that it was discovered in Lenawee county, Michigan, and presented several years ago to the Smithsonian Institute by Doctor Kost, and now constitutes No. 1634 of the Smithsonian collection.

Of the two skulls figured in this paper, the Smithsonian specimen from Lenawee county, Michigan, is by far the more complete. This and the skull described by Hall and Wyman, and known as the Clyde skull, are the two most perfect specimens known. The specimen found at Boicourt, Kan., although imperfect, still retains enough of the elements of the skull to warrant the restoration shown on plate 24, figure 8.

After a careful comparison between the Lenawee specimen, and with descriptions of other specimens, several differences occur in the first-mentioned skull which can scarcely be attributed to either age, sex or individual morphological differences. These variations, in the writer's estimation, should be considered enough of a specific character to determine it a different species from *C. ohioensis;* hence the name *C. kansensis* is proposed.

As a comparison, the well-known skull of *Castor fiber* has been used.

HISTORY OF THE BOICOURT SPECIMEN.

The skull figured on plate 26, figure *B*, was donated to the University of Kansas Museum about a year ago by Dr. J. R. McLeland, of Pleasanton, Kan. All that can be gathered relating to the history of the specimen is that about twelve years ago, while sinking coal shaft No. 2, three and a half miles southwest of Biocourt, Linn county, Kansas, in the valley of the Marais des Cygnes, a miner, Mr. W. J. Thirwell, came across the skull at a depth of thirty-four feet, in a layer of sedimentary material of a bluish color, which overlay a deposit of sandy conglomerate. At the time of the find the large incisor was complete, and other parts of the skull were present. For several years this fine specimen was kept in a cigar store, in a case along with the cigar boxes, unnoticed by anyone, until a year or two ago Doctor McLeland recognized in it a fossil form, secured it, and presented it to the University.

In the vicinity of Boicourt, and for several miles above and below, the river Marais des Cygnes has cut down to an average depth of from thirty to forty feet, and in many places the Bethany Falls limestone is exposed in considerable areas at the bottom of the river. About two and a half miles below where the specimen was exhumed, and just below the bridge that crosses the Marais des Cygnes at Trading Post, a small deposit of bones was found several years ago by Mr. Amos Tubbs, of Trading Post. This small collection the writer examined a year ago, and recognized in it teeth of elephant, horse, camel, together with limb bones and a tusk of an elephant, all belonging clearly to the Pleistocene. At the point where the bones were found, the river has cut clear down to the Bethany Falls limestone. Directly above the limestone occurs a layer of conglomerate about eighteen inches thick, above this a like thickness of bluish-gray silty deposit in which the bones were found. The depth at which these were discovered and the material in which they appeared tallies well with the data at hand concerning the *Castoroides* skull, so that it will not be unreasonable to suppose that at one time the layer in which the skull was found was once the old river bed, or the bottom of some body of water adjacent to the river. The fact that the bones found at Trading Post were in the same deposit and at about the same depth clearly indicates that *Castoroides* was contemporary with these forms.

To those unacquainted with the geology in the vicinity of Trading Post it may be well briefly to enumerate the layers as they occur where Mr. Tubbs' bone bed was exposed:

From the general level of the valley:
Six feet of black loam.
Twelve feet marly clay.
Twelve feet blue and yellow marl, verging into shale.
Eighteen inches of bluish silt in which the bones were found.
Eighteen inches conglomerate lying on the heavy Bethany Falls limestone.

The conglomerate beds and the blue silty material occur only in isolated patches of a few feet in length; that in which the bones were found was probably twenty-five feet in length.

THE SKULL.

The typically rodent-like skull more closely resembles that of *Castor fiber* than of any other of the rodent family, yet in many respects close analogies are found to that of the Bizacacha (*Lagostomus trichodactulus*), a living form found on the high pampas of South America. In tooth structure it more closely resembles this form than any other of the rodent family I have been able to examine, while the long diastema between the incisors and the molars, and rapid divergence of the molar series posteriorly and the general form of the basioccipital region also appear more Bizacacha-like. Although the molar teeth of these two forms look very similar on their grinding surface, there is quite a difference in their conformation. Those of the Bizacacha are made up of two laminæ of dentine and enamel in molars 1, 2, and 3, the fourth and last having three layers. The enamel does not form a true cylinder around the dentine, but only reaches part way around, there being no enamel wall on the posterior portion of the segments. In *Castoroides* each tooth has one more layer, a tooth being made up of tube-like sections composed of enamel and dentine, pressed nearly flat and fastened together with a layer of cement.

The dorsal surface of the skull is almost flat, broadening out posteriorly, and in the region of the lamboidal ridge is relatively more broad and massive than in *Castor.*

The narrowest part of the skull occurs just behind the cephalic ends of the parietals, instead of across the frontals as in *Castor.* Across the frontonasal sutures it presents a more massive appearance, and from here it tapers slightly to the tip of the nasals, which end rather abruptly and rounding. The facial portion of the maxilla composes a larger part of the zygomatic arch than does that element in *Castor,* and forms the major part of the front wall of the orbit. In consequence of this, the malar does not reach nearly so far forward, and has no contact with the lachrymal, while the contrary exists in *Castor,* where the front portion of the malar forms half of the anterior wall of the orbit. The squamosal extends further forward and commences higher up on the cranial portion than it does in *Castor,* and occupies about two-fifths the entire length of the skull, while the nasals are relatively more broad than long. The long and narrow parietal ridge rises sharply from the flat parietals to a height of ten millimeters. The interparietal is a relatively small element, almost unobservable, fitted wedge-like between the posterior ends of the parietals. The parietals themselves are long and very narrow, scarcely exceeding in width that of a full-grown beaver. The infraorbital foramen is located higher up the face than in *Castor.*

The diastema between the molar series and the massive incisor tooth differs much comparatively in the Lenawee and Boicourt specimens. In the former it measures 110 mm., in the latter 140 mm., and is, proportionately to the size of the skull, much longer.

A comparison of the large incisors of the two specimens reveals quite a difference in the markings of the outer enamel covering. In the Boicourt specimen the flutings are very narrow, and, counted from the anterior inner angle round to the posterior sinus, there are twenty-four. Correspondingly, the Lenawee skull shows only eighteen, while two of the fluted groovings on the anterior face of the teeth are exceedingly wide, the widest being 8 mm. from ridge to ridge, and widens out materially as it nears the extremity of the tooth.

In *Castor* the cutting edge of the incisors is worn nearly straight across, with slightly more wear on the outer edges, but in the *Castoroides* quite the reverse occurs, the teeth being worn thin and sharp at their junction on the medial line, and gradually get thicker and more heavy laterally, the two teeth thus forming a very efficient gouge.

A lateral view of *Castoroides*, when compared with *Castor*, shows quite a difference in contour of the dorsal part of the skull. In *Castor* the crest from supraoccipital to nasals shows quite a convexity, the highest part of which occurs at the junction of the parietals and frontals on the median line, and more strongly convexed at the caudal end of the nasals than at any other point, with the parietal ridge scarcely noticeable. In *Castoroides* the parietal and saggital ridge is very conspicuous, and is elevated 10 mm. above the parietals. From the supraoccipital ridge to the frontonasal suture on the median line it is nearly level; forward from here to the tips of the nasals it has a gentle slope. The malar is wider, thicker and more rounded than in *Castor*, with the lower portion gently converging inward. The cephalic edge, from the superior malomaxillary suture downwards, has a slightly more acute angle than has *Castor*. In *Castor* the malar on its outer face is nearly flat its whole depth from top to bottom. The squamosal is relatively much larger than in *Castor*, and extends higher up the sides of the cranium, thereby decreasing the width of the parietals. The infraorbital foramen in

Castoroides, compared with *Castor*, is decidedly larger, a third deeper than wide, and occupies a more dorsal position proportionally, having a long, deep fossa extending cephalad and dorsad, which is wider and shallower anteriorly. In *Castoroides* the superior portion of the maxilla in the orbitosphenoidal region is smoother, and does not have the excrescences caused by the roots of the molars as in *Castor*. With the exception of a few of the foramina of *Castoroides*, all obtain a proportional enlargement over *Castor*. One very noticeable exception is the small size of the external auditory meatus. In this there is but a slight difference in the actual size between the two, and is not nearly as large as that organ in Bizacacha. The tympanic bullæ in *Castoroides* are very small, and but little inflated, while the basioccipital is comparatively much broader and shorter. The double posterior nares, and the peculiarly constructed pterygoides, that have attracted the attention of all who have made a study of *Castoroides*, are beautifully shown in the Lenawee specimen belonging to the Smithsonian Institute. (See plate 25, fig. *A*, at *a-b*.) The mastoid in *Castoroides* is an exceedingly stout and massive bone, compared with *Castor*; the outer edge of this bone and the sternomastoid are deeply scored and pitted for heavy muscular attachment. The glenoid fossæ in *Castoroides* are shallow and broad, and would allow a more lateral motion of the lower jaws than would those of *Castor*. At the base of the auditory bullæ, and in front of the mastoid of *Castoroides*, occurs a deep and rough pit for muscular attachment that is not found in *Castor*.

On plate 27, figure *B*, a lateral view of the Boicourt specimen is given. The large broken incisor is withdrawn from its socket and the thin inner wall removed, showing the depth of the socket, which reaches back to the roots of the first molar, a thin partition only separating the pulpy root of the incisor from that of the molar. Just above, at *b* and *c*, are seen the frontal and nasal sinuses. A portion of the inner wall of the maxilla has been removed to show the last molar (*d*) as it lies in its alveolus, while at *e* is shown the brain cavity.

In Castoroides kansensis.

The basic occipital shows no sutural contact with the basic sphenoid, but is firmly coössified with that element, and while the conical projections mentioned by Wyman exist, they are situated more caudally and closer to the occipital condyle than in either the Lenawee specimen or that described by Wyman from Clyde.

The pterygoid, or wall between the internal pterygoid fossa and the inferior entrance to the posterior nares, rises immediately from the projection mentioned by Wyman, but at a point much farther back than in his specimen or that from Lenawee; consequently the pterygoids would be proportionally much longer transversely, while just behind and above the foramen rotundum two cavities, one above the other, occur, extending forward and upward, with the evidences of having a thin septum between the outer and inner walls of the internal pterygoid fossa.

Probably one of the most striking features of *Castoroides* is its enormous incisor teeth, which appear much out of proportion to the size of the molar teeth and skull.

The principal differences observed between the Lenawee and the Boicourt skulls, then, are: The proportionally larger incisors, with narrower grooves and greater number; the relatively longer diastema between the incisors and molars; the difference in the pattern of the folds in the last molar, and its comparative smallness; the difference in frontonasal region; comparatively longer nasals; and deep, rough pittings of the parietals.

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MEASUREMENTS OF THE TWO SKULLS.

	Lenawee county, Michigan, skull. *mm.*	*Boicourt, Linn county, skull.* *mm.*
Greatest length from tip of nasals to occipital condyle...	270	....
Nasals, greatest length....	93	110
Nasals, greatest width....	53	62
Frontals, greatest length....	84	....
Frontals, width at postorbito-frontal suture....	84	....
Parietal, length	133	....
Parietal, width at point opposite squamosal	53	61
Molars, length of series....	68	76
Grinding surface of first molar, length....	17	20
Grinding surfaces of first molar, width....	16	19
Grinding surface of last molar....	20	20
Incisor, lateral diameter at level of alveolus....	24	28
Incisor, transverse diameter....	21	25
Occiput, transverse diameter....	140	....
Occiput, vertical diameter....	67	....
Depth of skull, level of molars to frontal bosses....	110	120
Length of diastema between incisor and first molar....	110	140

THE

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CONTENTS:

II. CYTOLOGICAL STUDIES OF FEMUR-RUBRUM AND OTHER MELANOPLI.
Nadine Nowlin.

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CYTOLOGICAL STUDIES OF *FEMUR-RUBRUM* AND OTHER *MELANOPLI.*

BY NADINE NOWLIN.

(Plates 28-32)

(Contribution from the Zoological Laboratory, No. 200.)

FIFTEEN years ago Wilcox ('95) published a paper on the spermatogenesis of *Melanoplus femur-rubrum,* or *Caloptерus femur-rubrum,* as the genus was then called. It is generally conceded that many of his interpretations are incorrect, but up to the present time his work stands as the only description of this species. Since it is my purpose to examine the chromosome complexes of as many genera of *Melanoplus* as possible, it seemed advisable to give emphasis to the discussion of this particular one.

Of the some dozen species that I have examined, *femur-rubrum* is perhaps the least favorable for study. The stage in which the chromosomes separate well are very short, and counts are difficult. This may explain some of the errors that Wilcox made.

MATERIAL AND METHODS.

The grasshoppers were collected in September, 1910, on the south campus of the University of Kansas. This is not the best time for collecting, as the germ cells are nearing the end of their activity, but all stages can be found from spermatogonia to spermatozoa. Wilcox's material was collected also in the fall. I have used Flemming's and Bouin's fluids for preserving, and both gave good results. Heidenhain's iron-hæmatoxylin was the chief stain, but Flemming's tricolor was also tried.

DESCRIPTION.

Melanoplus femur-rubrum.

Spermatogonia.

It was somewhat difficult to find clear spermatagonial plates, as the chromosomes crowd very closely at this phase, and the bent form of the rodlike chromosomes seldom lie in one plane. Their general arrangement is radial, one end of the rod pointing toward the center of the cell. Figure 5 is an unusually fortunate cut, which shows the radial arrangement very well. Many of the chromosomes are in cross sections, though two or three pairs of small spherical ones occur rather constantly through the later generations. The chromosomes can be paired fairly accurately in such a view as figure 5.

Going back to an earlier stage in the development of such a cell, we find the chromatin in the form of a slender spireme, radiating from a black mass lying close to the nuclear membrane. (Fig. 2, pl. 28.) This body is probably the accessory chromosome. The spireme is irregular, giving a beaded appearance. I take figure 3 to represent the next stage. It lies in an adjoining cyst. The thread has thickened, segmented across, and shows a longitudinal split. At figure 4 is shown a still further condensation of chromatin. Chromosomes are now formed which look vacuolated, and one is distinctly separated from the others by a membrane. Such an isolation of the accessory is typical of *Brachystola* and other genera. The metaphase, viewed from the side of the spindle, looks somewhat like a second spermatocyte, but here, of course, the chromosomes are more numerous and crowded, and the spindles smaller. An equatorial plate has been described at the beginning of this section. It shows twenty-three chromosomes when all are present, and in many of the cells it is not difficult to identify the chromosomes of spermatognia and spermatocytes.

Oögonia and Female Somatic Cells.

A study of developing oögonia was made in the hope of getting clearer plates than in the male, but the cells are very small when division takes place. After division rapid growth occurs, in which the chromatin forms a fine spireme, much beaded in appearance. (Fig. 12.) The nucleus grows as well as the cytoplasm, the fine chromatin threads expanding into broad, faintly staining bands. (Fig. 13.) Finally the chromatin forms faint rings (figure 14), and the oögonia have all the appearance of cells in prophase, but instead of continuing division, now there follows a long rest and further growth stage, in which the nucleus takes the typical germinal-vesicle form, and the cytoplasm fills with yolk.

Many dividing somatic cells are to be found around the growing eggs in the follicular tissue. Numerous attempts to count the chromosomes were made, and the greatest number found was twenty-two. I take this to be incorrect, however, as counts on other female cells have given twenty-four. In *Stenobotherus* (McClung 11) there are twenty-two chromosomes in the female, but two of these are multiples. I have not been able to identify any multiple in *femur-rubrum.*

Wilcox says, on page 9 ('95): "I could not determine how many divisions the spermatogonia undergo. The chromosomes in the prophases are twelve in number, twenty-four at the equator of the spindle, during metakinesis. The individual chromosomes are rod shape, or often elongate spindle shape. In metakinesis they show ordinarily the well-known V-shaped figures, and are connected with each other in pairs by means of linin fibers." Whether this writer had confused second spermatocyte and spermatogonia I do not know. At any rate, his count for spermatogonia is incorrect. And it is even more peculiar that he considered the divided twelve as twenty-four chromosomes instead of two newly formed cells, each with twelve chromosomes.

Spermatocytes.

The early spermatocytes show faintly staining nuclei, with chromatin scattered in loose threads of varying lengths. The threads seem irregular in diameter, giving the effect of a greater amassing of granules at certain points. (Fig. 16.) The threads assume more definite outlines later and become finer. They still have the beaded appearance, and at one time form a bouquet stage, all looping out of a darkly staining chromatin mass at the periphery of the nucleus. (Fig. 17.) The beaded appearance is seen just before the spireme breaks up (figs. 19, 20), and even in the early chromosomes this appearance is retained. Wilcox believed that four of these nodules are grouped together to form the tetrad, and that what we know as the tetrad is made up of four chromosomes. He believes the first spermatocyte division effects the separation of two of the chromosomes from the other two of the original quadrivalent group. And in the second division the remaining chromosomes that have hung together in pairs are parted.

I believe his whole error has come about through the beaded appearance of the spireme. It is true that there are distinct nodules in this thread, and that in the formation of the chromosomes one sees often four knots to a single thread, but one sees many more sometimes. Instead of considering them individual chromosomes, we must believe that they are mere irregularities in the amassing of granules during spireme formation.

We get some cells which show a very clear case of a continuous spireme. (Fig. 18.) The chromosomes in the early prophases are in the form of rings and crescents. The very early rings show sometimes the longitudinal split, but it is seldom. The first tendency in the condensing of the chromosomes is to form rings, thus in figure 2, plate 29 many are seen. When they begin to arrange for division we see fewer, usually from two to three. Some are crosses, and even in the prophase have begun dividing. (Fig. 3.) There are twelve chromosomes, then, in the first spermatocytes, formed, as I believe, by the union of the pairs of spermatogonial chromosomes; one of these is the accessory and is unpaired. (Fig. 16.) This special chromosome moves toward the pole ahead of the others undivided (figs. 1, 2, 4, pl. 30), and in equatorial plate is seen always in a different plane from the rest. The remaining eleven divide longitudinally (figs. 1, 2, 3, 4), so that the number of chromosomes distributed to the daughter cells is eleven and twelve respectively. We see the two sets of plates, then, in the second spermatocytes. (Figs. 6, 7.) By means of a cross division of these chromosomes the eleven diads are separated. The accessory divides longitudinally. Thus we see that half the spermatids have eleven chromosomes plus the accessory (fig. 6), and half have the eleven and no accessory (fig. 7).

Spermatids.

While the chromatin amasses at the poles of the new spermatids (fig. 11), the cytoplasm of the cells grows rapidly. The nuclear mass breaks up into a beaded appearance once more (fig. 12) and the cytoplasm begins to condense. There follows an unequal growth of nucleus and cytoplasm now, the nucleus gaining on the cytoplasm, as seen in figures 13, 14, 15. At the same time the chromatin moves to the nuclear boundary, where it forms a darkly staining band. The cytoplasm begins to elongate at one side of the nucleus until a condition seen in figure 17 is reached. The remainder of the marked metamorphosis of the cell consists of a condensing of material until a small, elongated nuclear head remains, and a long vibratile fiber. (Fig. 25.)

Melanoplus differentialis.

A glance at plate 31 will show that *differentialis* follows very closely the description for *femur-rubrum.* There are from one to two and occasionally three rings seen in an equatorial plate of the first spermatocyte, and there is a tendency for most of the larger chromosomes to form rings in the prophase. Thus we may see three or four rings at one time. *Differentialis* is the most favorable material of the *Melanoplus* group thus far investigated. The chromosomes are a little larger than *femur-rubrum* and have the advantage of not crowding so much.

Melanoplus atlanis.

Figures 1 to 12, plate 32, show spermatocyte divisions in *M. atlanis.* A comparison of this species with the two preceding shows that the chromosomes are more irregular in form, but as to general behavior, numbers, etc., are the same.

Melanoplus packardii.

Plate 32, figures 13 to 24, show a few of the stages of division in *M. packardii.* The chromosomes of this group are smaller than any of the preceding, but in general behavior and form are similar.

SUMMARY AND DISCUSSION.

In the four species of *Melanoplus* set forth in this paper we find a close similarity in form and behavior of the chromosomes in the different generations, and an identity in number throughout. That is to say, twenty-three spermatogonial chromosomes and twelve spermatocyte. The counts in the female cells did not give more than twenty-two, but there is much room for doubt, owing to crowded plates. The results of this paper tally with those on *Melanoplus bivitatus* Say ('08).

Femur-rubrum and atlanis are so similar in body form that they are easily mistaken for each other. Size, coloring and shape are alike, the distinction lying in the podical plates only. The chromosome complexes of the two species are, however, not as similar as those of *femur-rubrum* and *differentialis*. Between the two latter is a marked difference in body size, yet the chromosomes are the same in size and shape. There is no size difference in the chromosomes of *M. femur-rubrum* and *M. atlanis*, but the form of *atlanis* chromosomes is more irregular.

On the whole, the close resemblance between the complexes of the five species examined supports the belief that there is correlation between chromosomes and body characters.

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EXPLANATION OF PLATES.

All drawings made with a 12 ocular, one-twelfth oil immersion obj. and Abbe camera lucida; reproduced at a magnification of about 2000 diameters. Drawings are arranged in the order of their development as nearly as possible, beginning with spermatocytes and ending with spermatogonia. Figures 1-65, plates 28, 29, 30, represent *Melanoplus femur-rubrum;* plate 31, *Melanoplus differentialis;* and plate 32, figures 1-12, *Melanoplus atlanis,* figures 13-24, *Melanoplus packardii.*

EXPLANATION OF PLATES.

PLATE 1.

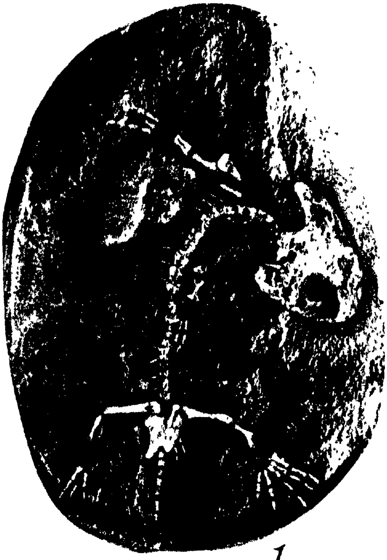
FIG. 1.—The nodule containing the remains of *Amphibamus grandiceps* Cope. X 1. (No. 1234, Yale Museum.)

FIG. 2.—The opposite half of the same nodule. X 1.

FIG. 3.—*Erierpeton branchialis* Moodie. X 1. (No. 801, Yale Museum.)

FIG. 4.—*Cephalerpeton ventriarmatum* Moodie. X 1. (No. 796, Yale Museum.)

PLATE 1.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4

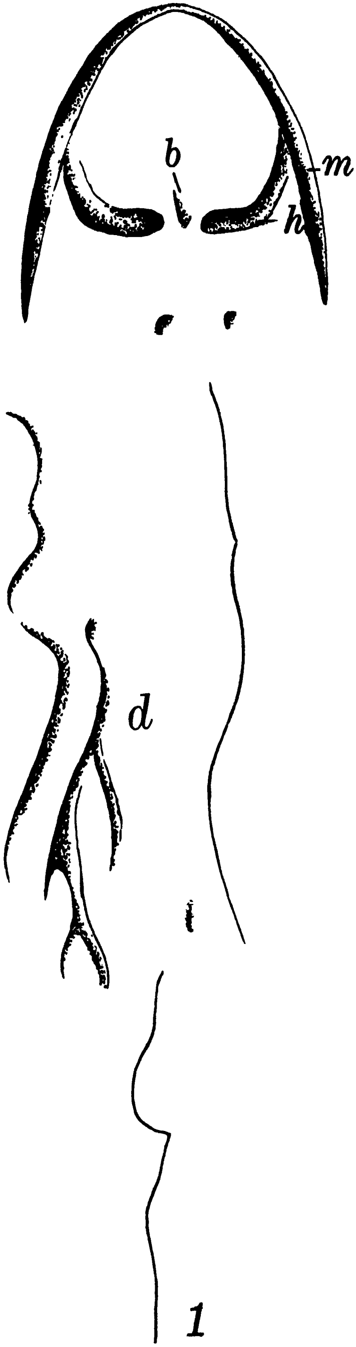
PLATE 2.

FIG. 1.—Drawing of the specimen of *Erierpeton branchialis* Moodie. X 3. *b*, basibranchial; *d*, body impressions; *h*, hypohyal; *m*, mandible.

FIG. 2.—The arm skeleton of *Erpetobrachium mazonensis* Moodie. X 2. *cl*, clavicle; *h*, humerus; *r*, radius; *s*, scapula; *u*, ulna.

FIG. 3.—Rib of *Mazonerpeton costatum* Moodie. X 4. (Yale Museum.)

PLATE 2.



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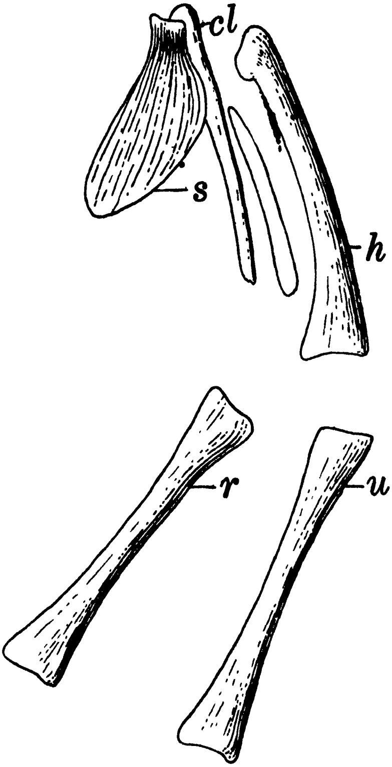

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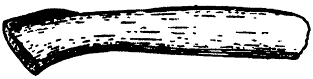

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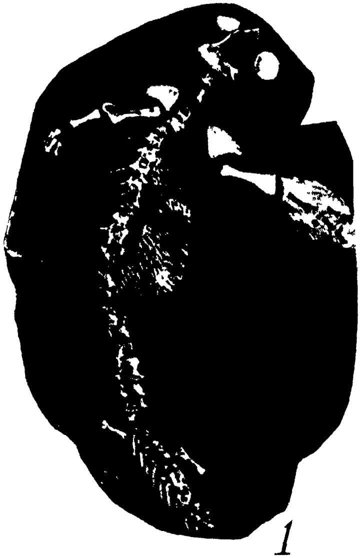
PLATE 3.

Figs. 1 and 2.—The halves of the nodule containing the skeleton of *Mazonerpeton longicaudatum* Moodie. X 1. (No. 795, Yale Museum.)

Fig. 3.—The larger specimen of *Eumicrerpeton parvum* Moodie. X 1. (No. 803, Yale Museum.) Shows impressions of intestines.

Fig. 4.—The smaller specimen of *Eumicrerpeton parvum* Moodie. X 1. (No. 802, Yale Museum.) Shows mold of intestines.

PLATE 3.



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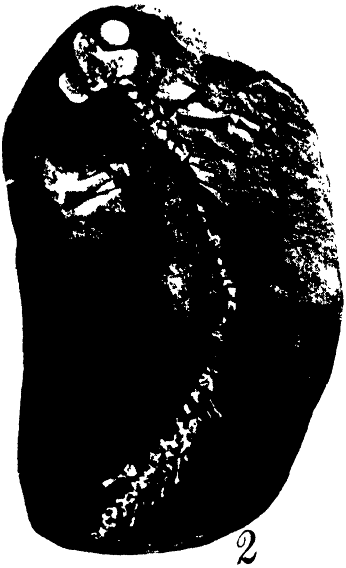

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PLATE 4.

An ideal restoration of *Eumicrerpeton parvum* Moodie in surroundings of Carboniferous plants as they are preserved in the nodules from Mazon Creek, where they are associated with the Amphibia. The size of the animal in life was from an inch and a half to two inches in length.

PLATE 4.

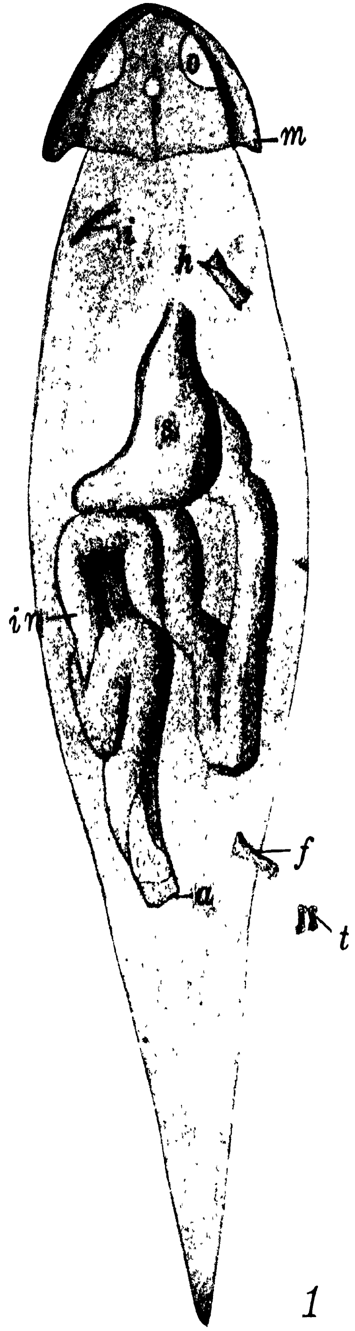
PLATE 5.

FIG. 1.—Drawing of the third specimen of *Eumicrerpeton parvum* Moodie. X 4. (No. 4400, United States National Museum.) *a*, anus; *f*, femur; *h*, humerus; *i*, interclavicle (?) clavicle; *in*, intestine; *m*, mandible; *o*, orbit; *s*, stomach; *t*, tibia and fibula.

FIG. 2.—Drawing of the skeleton of *Amphibamus thoracatus* Moodie. X 2. (No. 4306, United States National Museum.) *c*, clavicle; *h*, humerus; *i*, interclavicle; *o*, orbit; *r*, radius; *v*, vertebra.

FIG. 3.—Cope's drawing of the type specimen of *Amphibamus grandiceps* Cope. X 1 ca. (Geol. Survey Illinois, vol. 2, pl. 32.)

PLATE 5.



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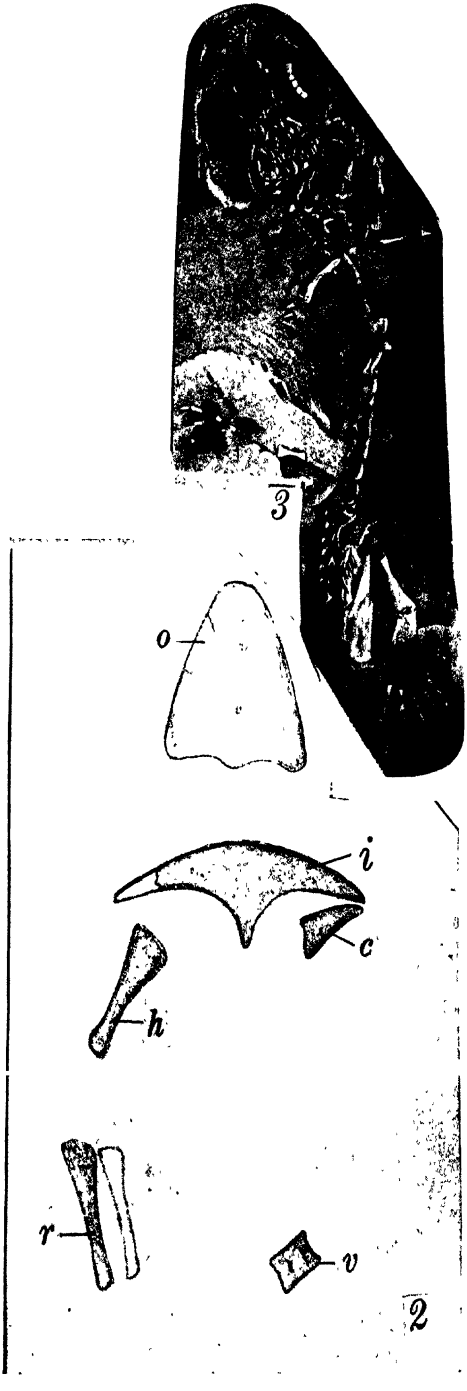

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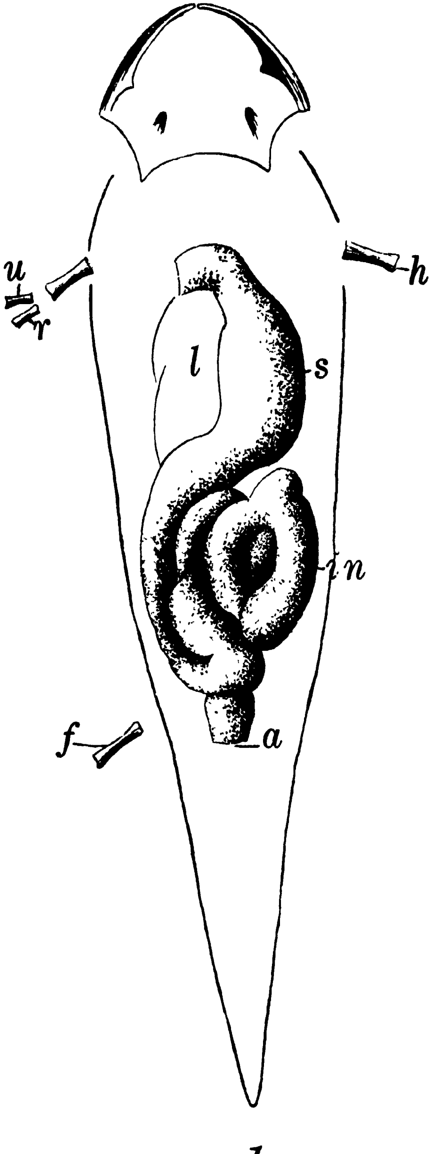
PLATE 6.

FIGS. 1 AND 2.—Drawings of the Yale specimens of *Eumicrerpeton parvum* Moodie. (X 4½ and 4.) *a,* anus; *d,* dorsal lateral line; *f,* femur; *h,* humerus; *in,* intestine; *l,* liver impression; *m,* median lateral line of the tail; *o,* orbit; *p,* parietal; *r,* radius; *s,* stomach; *u,* ulna.

PLATE 6.



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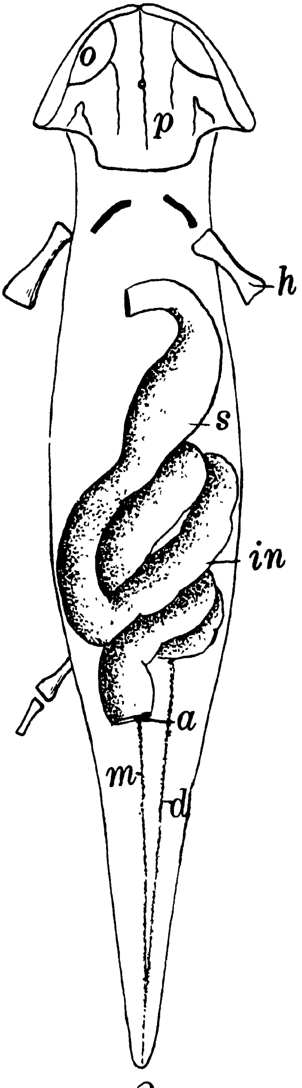

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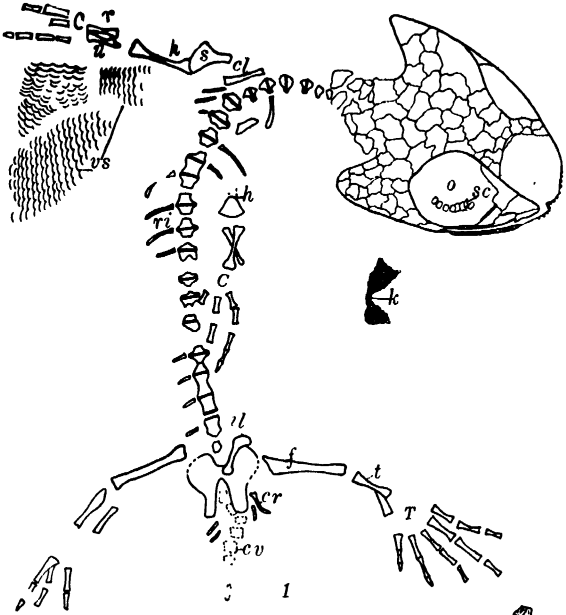
PLATE 7.

FIG. 1.—Drawing of the skeleton of *Amphibamus grandiceps* Cope, in Yale Museum. (X 1¼.) *C*, carpus; *cl*, clavicle; *cr*, caudal ribs; *cv*, caudal vertebræ; *f*, femur; *h*, humerus; *k*, a piece of skin; *il*, ilium; *o*, orbit; *r*, radius; *ri*, ribs; *s*, scapula; *sc*, sclerotic plates of the eye; *u*, ulna; *vs*, ventral scutellæ; *t*, tibia; *T*, tarsus.

FIG. 2.—Drawing of the skeletal remains of *Cephalerpeton ventriarmatum* Moodie. X ½. Lines to the right of the skeleton represent boundary of the nodule. *a*, prefrontal; *cl*, clavicle; *d*, dentary; *h*, humerus; *f*, frontal; *j*, jugal; *m*, maxilla; *o*, orbit; *p*, phalanges; *pa*, parietal; *pr*, postorbital; *r*, radius; *s*, sclerotic plates; *u*, ulna; *vs*. ventral scutellæ.

FIG. 3.—Drawing of the skeleton of *Mazonerpeton longicaudatum* Moodie. X 2. *C*, carpus; *cl*, clavicle; *cv*, caudal vertebræ; *f*, femur; *h*, humerus; *r*, radius; *ri*, rib; *s*, scapula; *sc*, sclerotic plates; *vs*, ventral scutellæ; *u*, ulna.

PLATE 7.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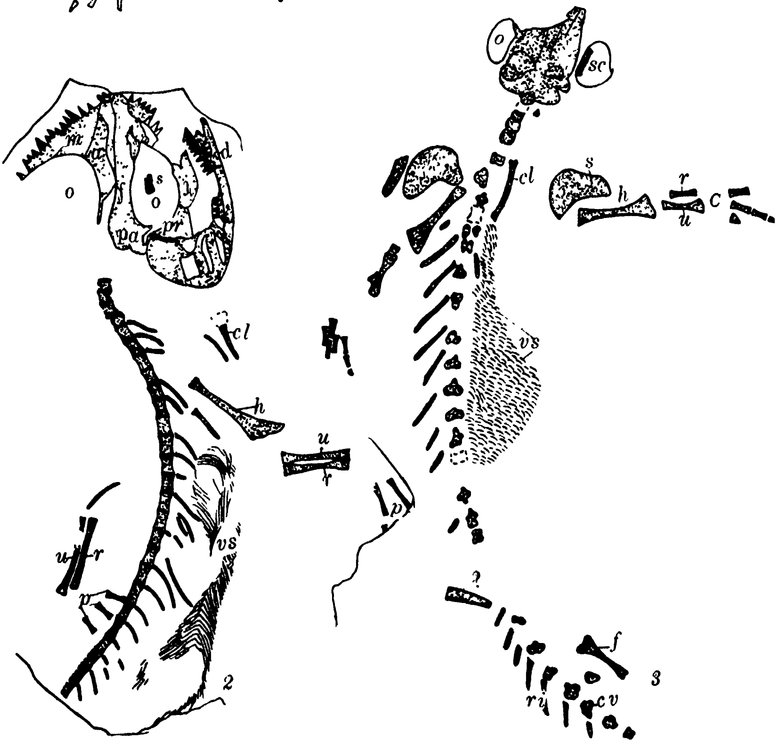
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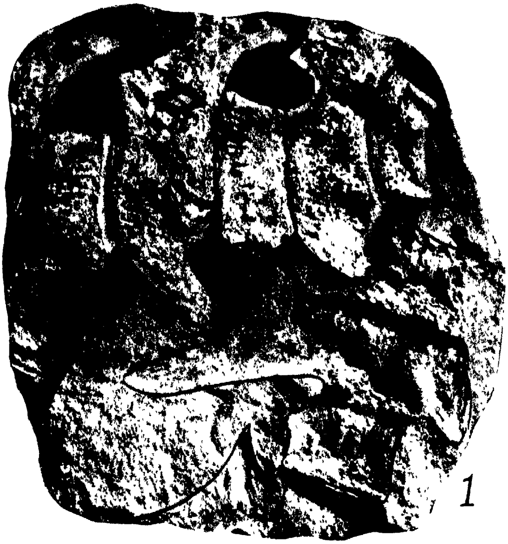
PLATE 8.

Figs. 1 and 2.—The two halves of the nodule containing the vertebræ of *Spondylerpeton spinatum* Moodie. X 1. (No. 793, Yale Museum.)

Fig. 3.—The arm elements of *Erpetobrachium mazonensis* Moodie. X 1. (No. 799, Yale Museum.) *h*, humerus; *r*, radius; *s*, scapula; *u*, ulna.

Fig. 4.—The skeleton of *Mazonerpeton costatum* Moodie. X 1. (No. 800, Yale Museum.)

PLATE 8.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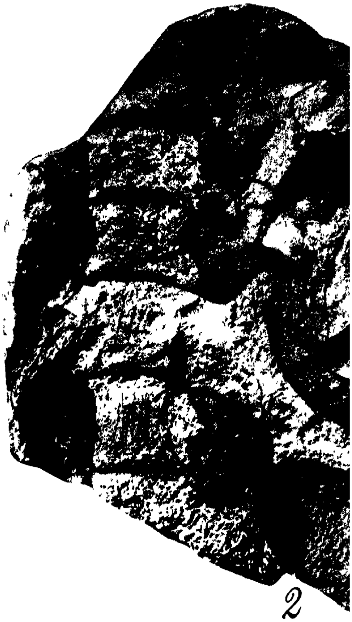
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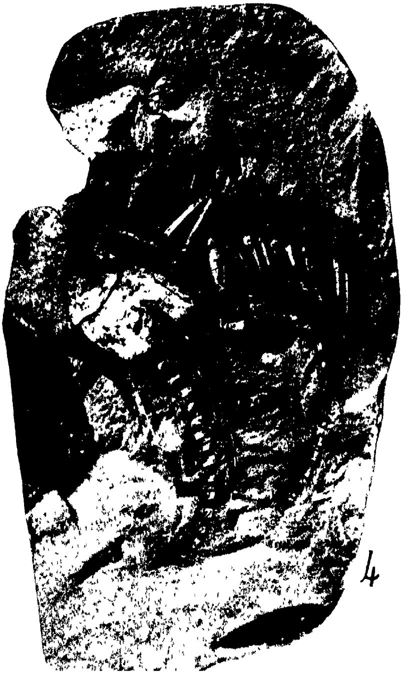
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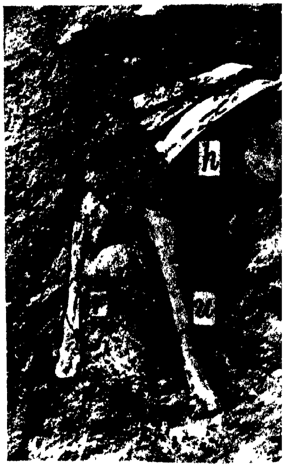
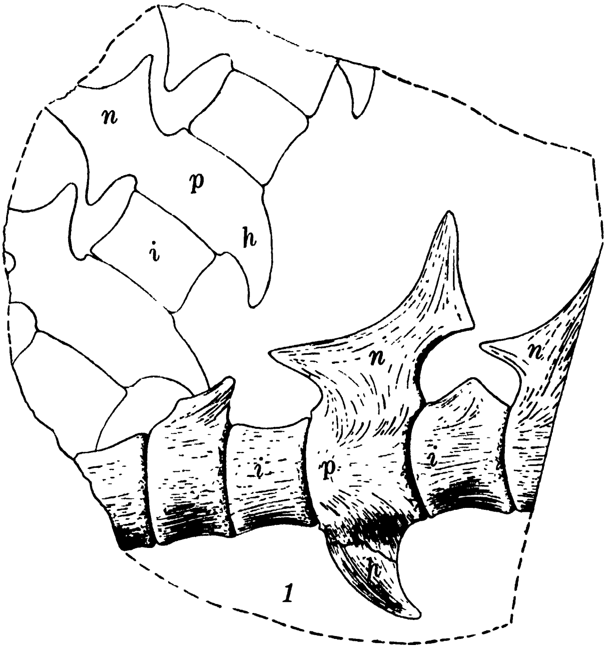


PLATE 9.

FIG. 1.—Drawing of the vertebral remains of *Spondylerpeton spinatum* Moodie. X 1. *h,* chevron; *i,* intercentrum; *n,* neural spine (neurocentrum); *p,* pleurocentrum.

FIG. 2.—The skeletal remains of *Mazonerpeton costatum* Moodie. X 2. *ac,* anterior caudal; *ch,* chevron; *cl,* clavicle; *cv,* caudal vertebræ; *f,* femur; *h,* humerus; *m,* mandible; *r,* ribs; *v,* vertebra; *sk,* skull.

PLATE 9.



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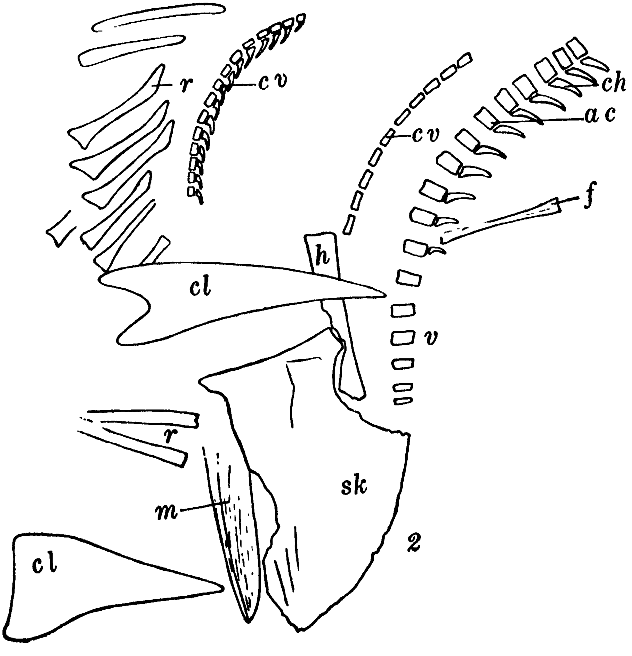

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PLATE 10.

Ideal restoration of *Mazonerpeton* crawling on calamite stems and about to feed on an *Acanthotelson*. Drawn from the fossils.

PLATE 10.

PLATE 11.

Photographs of the two halves of the nodule containing the remains of *Amphibamus grandiceps* Cope, in the possession of Mr. L. E. Daniels, of Rolling Prairie, Ind. This specimen shows the form of the body and a large part of the skeletal structure. The orbits are blackened with the *pigmentum nigrum* of the iris.

PLATE 11.

PLATE 12.

Restoration of the skeleton of *Amphibamus grandiceps* Cope, on the basis of the Yale specimen, the specimen in Mr. Daniels' possession, and Cope's drawing of the type. The outline of the body is restored from the specimen in the possession of Mr. Daniels, as may be seen by referring to plate 11. *Ca,* capus; *Cl,* clavicle; *E,* epiotic plate; *Fe,* femur; *Fi,* fibula; *F,* frontal; *Hu,* humerus; *Ic,* interclavicle; *Il,* ilium; *Is,* ischium; *J,* jugal; *L,* lachrymal; *M,* maxilla; *N,* nasal; *O,* orbit; *P,* parietal; *Pf,* postfrontal; *Po,* postorbital; *Pr,* prefrontal; *Px,* premaxilla; *Pu,* pubis; *Qj,* quadratojugal; *R,* radius; *So,* supraoccipital plate; *Sq,* spuamosal; *sr,* sacral rib; *St,* supratemporal (squamosal) (paraquadrate); *Sc,* scapula; *Ta,* tarsus; *Ti,* tibia.

PLATE 12.

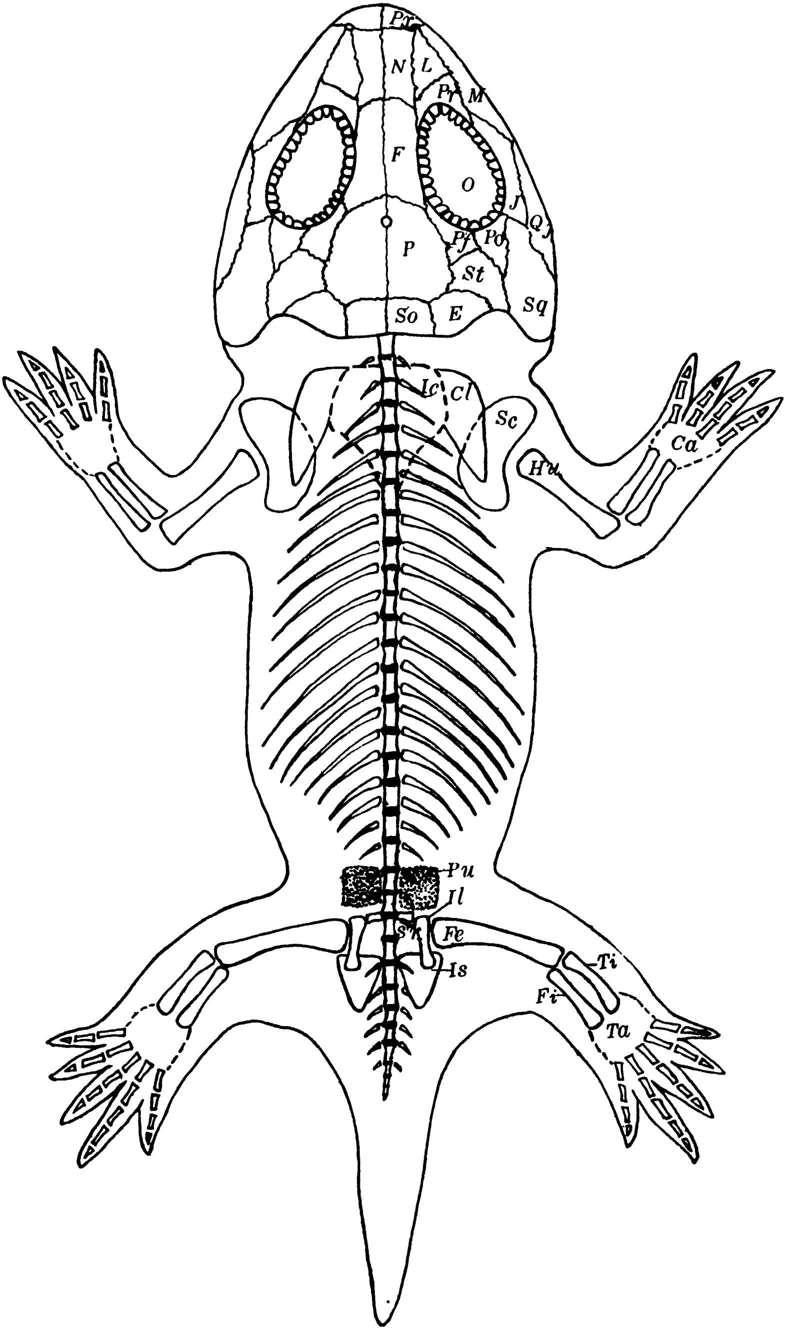
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PLATE 13.

Restoration of *Amphibamus grandiceps* Cope as it probably appeared in life.

PLATE 13.

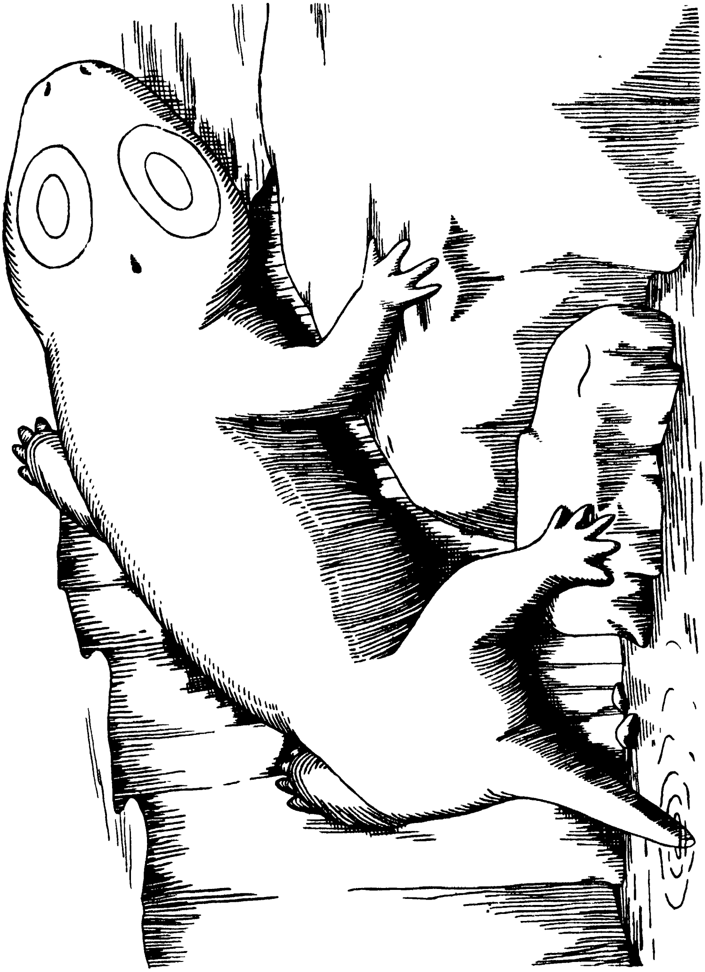


PLATE 14.

Branchiosauria from the Upper Carboniferous (Commentry beds) of France.

FIGS. 1, 2, 3, 8 AND 9.—*Branchiosaurus (Protriton) fayoli* Thevenin. Specimens showing the external form of the body and portions of the skeleton.

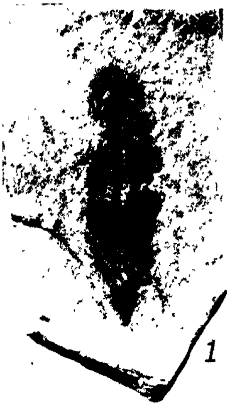
FIG. 4.—An enlarged view of the ventral scutellæ of *Branchiosaurus fayoli* Thevenin. X 15.

FIG. 5.—The entire form of the ventral scutellæ of the same species.

FIG. 6.—A specimen of *Branchiosaurus fayoli* Thevenin, showing sclerotic plates and external branchiæ. X 2.

FIG. 7.—A complete specimen of *Branchiosaurus (Protriton) petrolei* Gaudry, showing external branchiæ. From the Lower Permian of Autun. X 1. All figures after Thevenin.

PLATE 14.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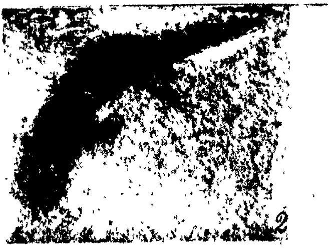
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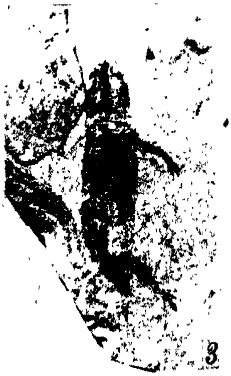
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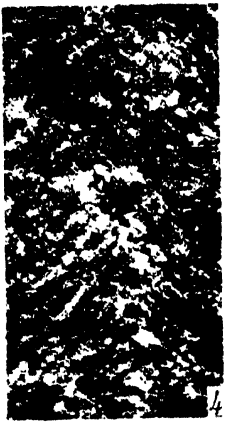
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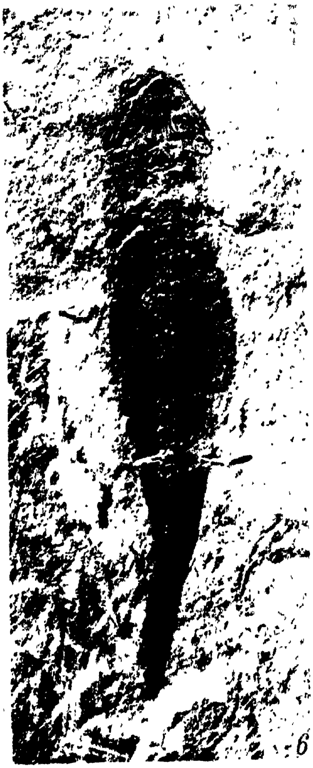
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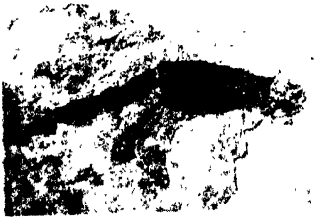
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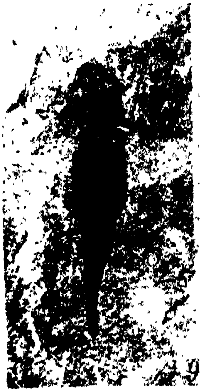
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PLATE I.

FIG. 1.—Flowering branch of *Krameria canescens*. × ⅜.

FIG. 2.—Root showing knotty crown and numerous secondary roots. × ½.

PLATE I.

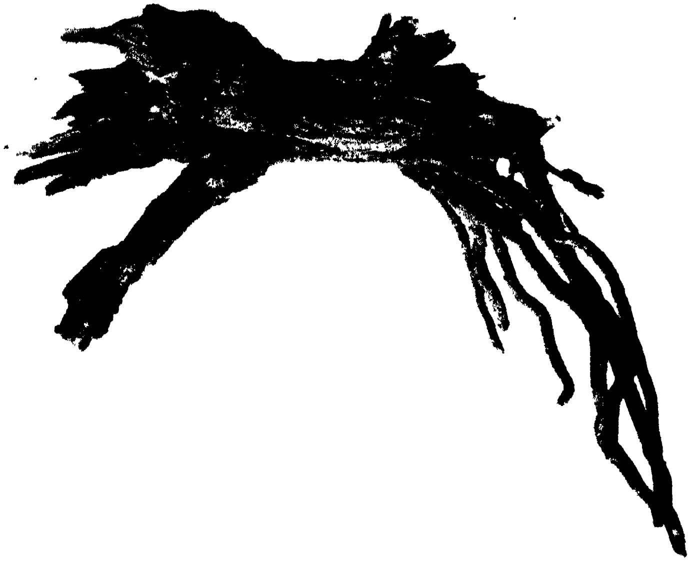

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PLATE II.

FIG. 3.—Cross section of stem, showing one year's growth: *e*, epidermis, with the cuticle represented by the outer black circle; *p*, palisade; *y*, thin-walled parenchyma of primary cortex; *n*, pericycle; *d*, endodermis, *a*, bast fibers; *o*, phloëm; *x*, xylem; *r*, medullary ray; *m*, medulla. × 78.

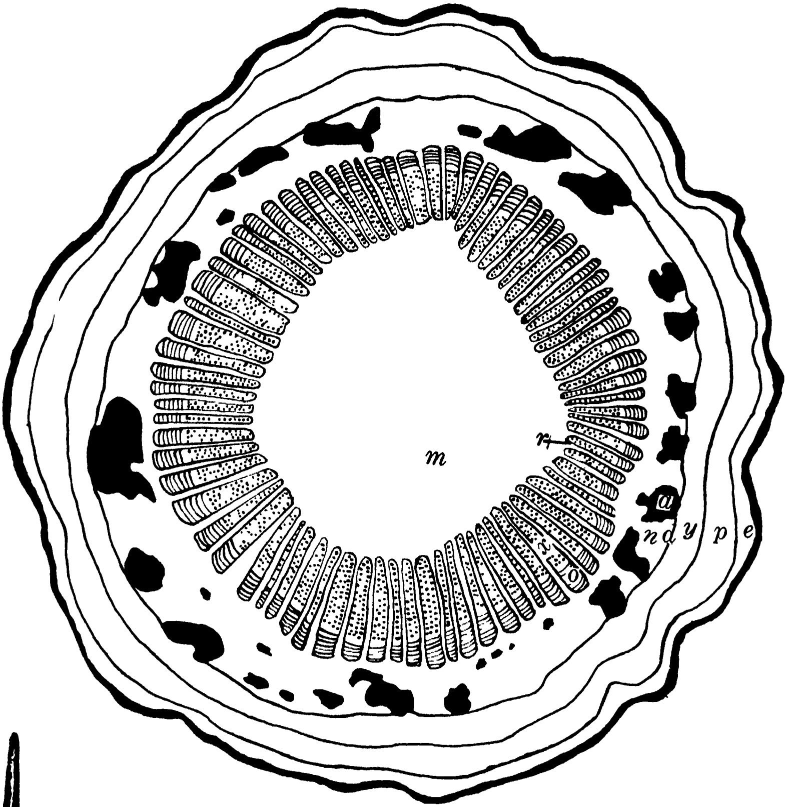
FIG. 4.—Cross section of secondary root: *s*, brown scaly cork; *g*, cork, the cells filled with reddish-brown coloring matter; *v*, phellogen; *l*, thin-walled parcenchyma; *f*, phloëm; *w*, xylem; *u*, cambium. × 10.

FIG. 5.—Small portion of stem: *c*, cambium; *t*, tracheids; *r*, medullary ray. × 475.

FIG. 6.—Bast fibers, and parenchyma of the pericycle of stem. × 325.

FIG. 7.—Tracheid from stem. × 325.

PLATE II.



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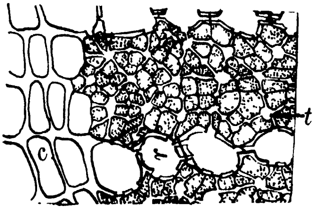

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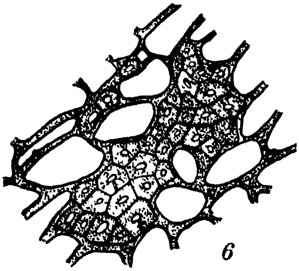

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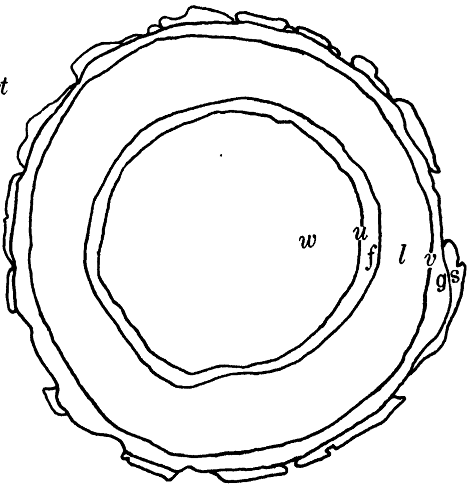

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PLATE III.

FIG. 8.—Cross section of a small portion of a stem 4.6 mm. in diameter: *e*, epidermis, the cuticle represented by the black outer band; *x*, palisade; *q*, thin-walled parenchyma of primary cortex; *y*, pericycle; *c*, cambium; *w*, water tubes; *m*, medullary rays; bast fibers are shown in the phloëm and pericycle by black dots. × 65.

FIG. 9.—Longitudinal radial section of stem: *u*, spiral water tube; *l*, reticulate water tube; *f*, medulla. × 288.

FIG. 10.—Portion of phloëm: *b*, bast fibers; *r*, medullary rays. × 325.

FIG. 11.—Longitudinal radial section of stem phloëm: *b*, bast fiber; *n*, undivided mother cells. × 325.

FIG. 12.—Stem tracheids. × 288.

FIG. 13.—Stem bast fiber. × 90.

FIG. 14.—Tangential section of stem cork. × 325.

PLATE III.

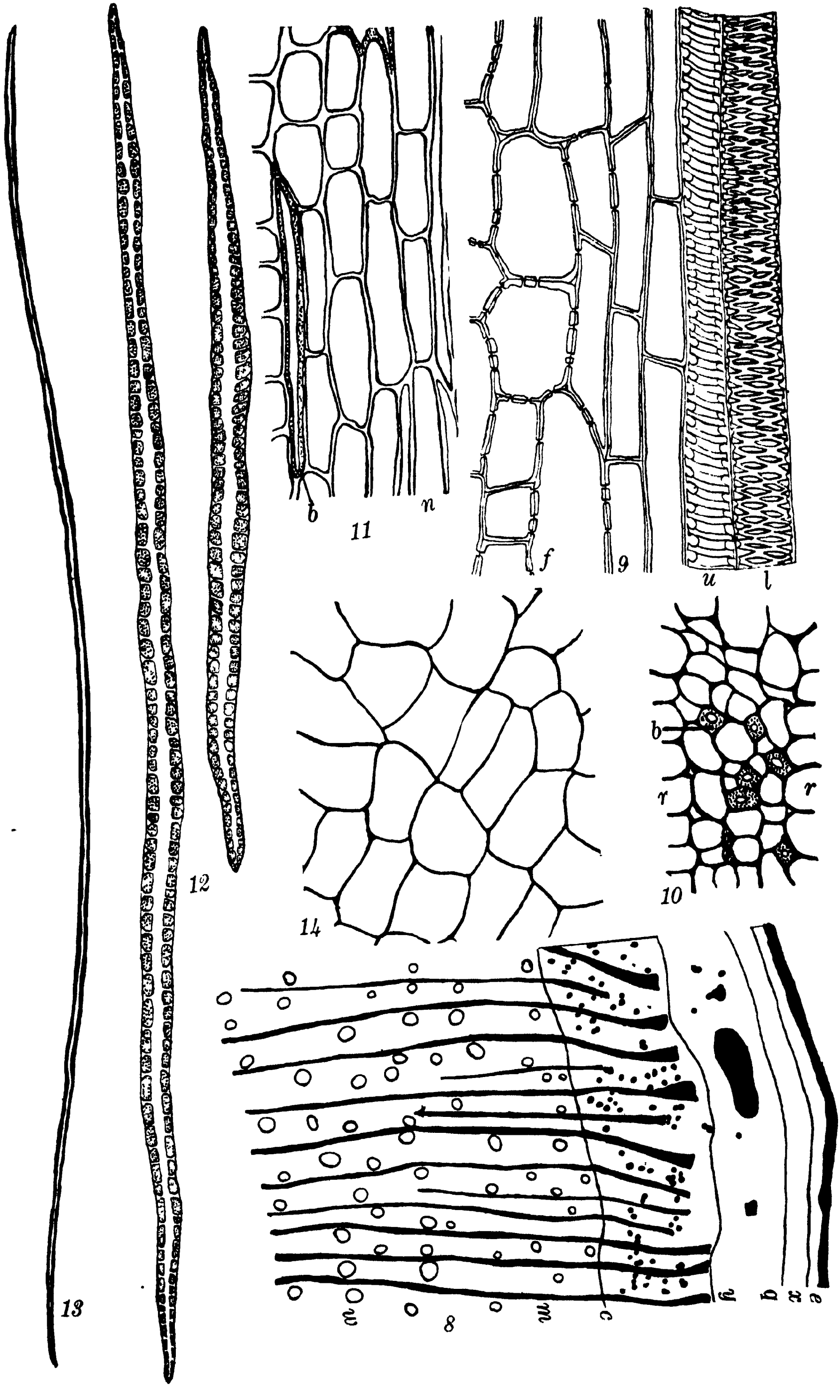


PLATE IV.

FIG. 15.—Portion of stem: *t*, trichomes; *e*, epidermis; *y*, palisade; *bf*, bast fibers. × 325.

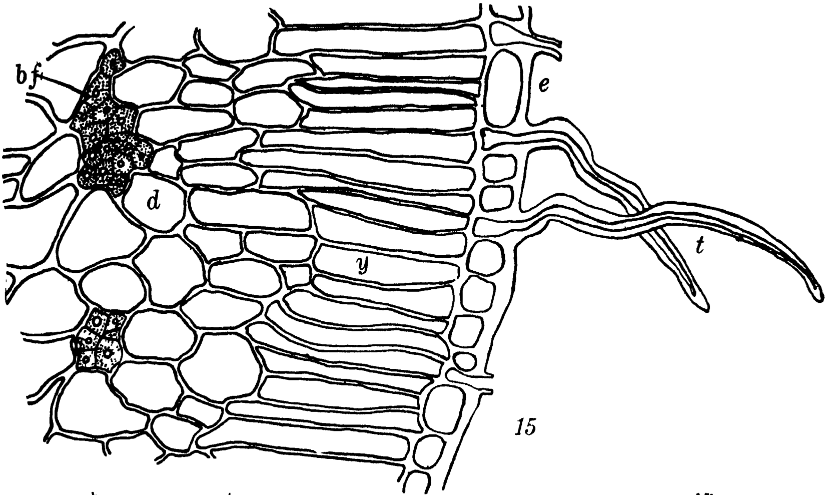
FIG. 16.—Surface view of stem epidermis: *s*, stoma; *h*, scar of trichome. × 175.

FIG. 17.—Cross section of stem, one year old, showing longitudinal section of a stoma: *st*, *p*, palisade; *cl*, chloroplasts; *g*, guard cell; *i*, air chamber; the cuticle is shaded black. × 475.

FIG. 18.—Longitudinal section of stem, showing cross section of a stoma. × 475.

FIG. 19.—Longitudinal radial section of stem cambium: *c*, cambiform cell of the phloëm. × 325.

PLATE IV.



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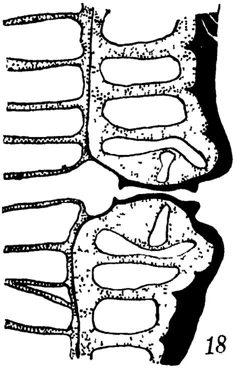

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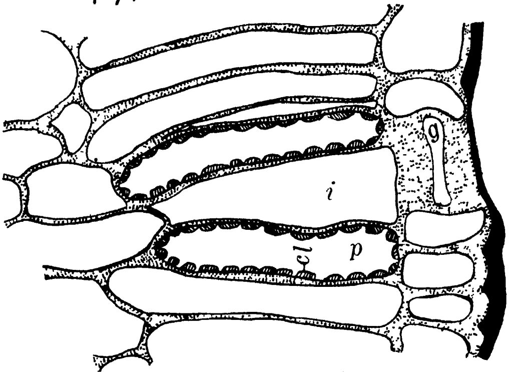

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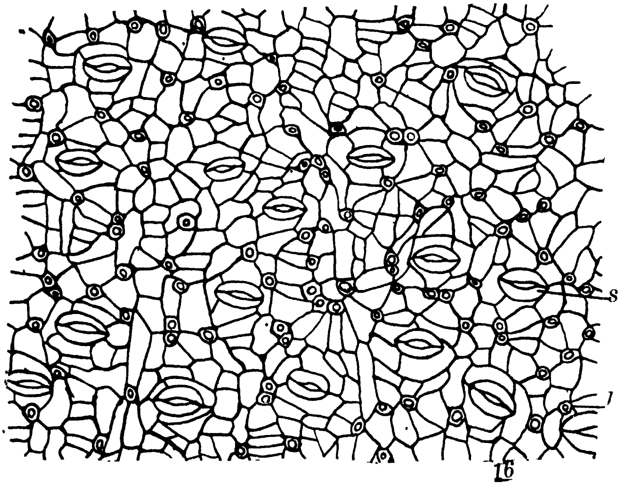

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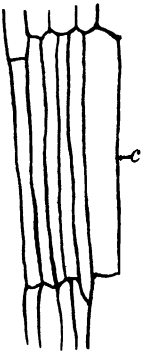

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PLATE V.

FIG. 20.—Longitudinal radial section of stem medullary ray. × 475.

FIG. 21.—Longitudinal tangential section of stem medullary ray. × 475.

FIG. 22.—Longitudinal tangential section of stem wood parenchyma. × 475.

FIG. 23.—Cross section of stem tracheids; and wood parenchyma, *w*. × 475.

FIG. 24.—Cross section of a small portion of a root; *p*, phloëm; *c*, cambium; *m*, medullary ray; *x*, xylem. × 325.

FIG. 25.—Pith from cross section of one-year-old stem. × 325.

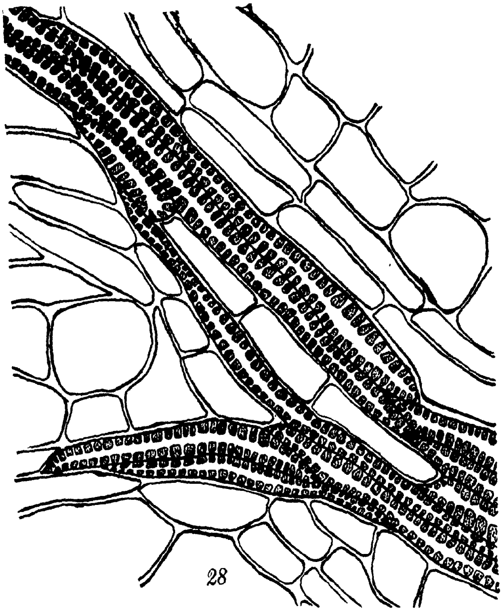
FIG. 26.—Longitudinal section of a stem water tube. × 288.

FIG. 27.—Surface view of a small portion of a water tube. × 288.

FIG. 28.—Tracheids and parenchyma cells from a leaf cut longitudinally through the broad diameter. × 475.

FIG. 29.—Cambiform cells from the phloëm of a leaf, cut longitudinally through the narrow diameter. × 325.

PLATE V.



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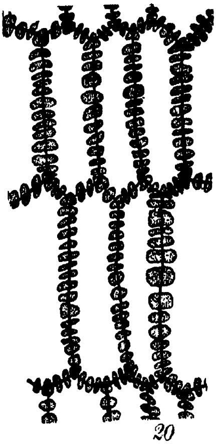

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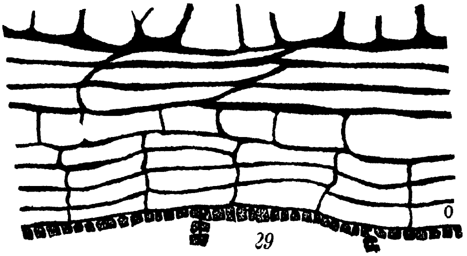

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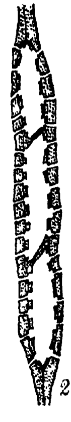

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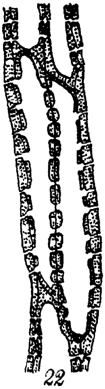

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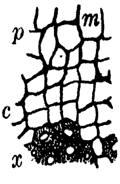

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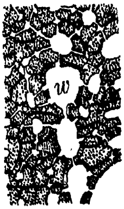

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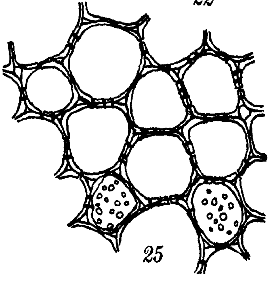

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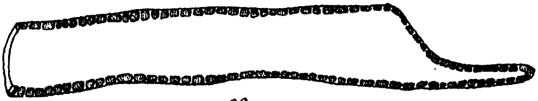

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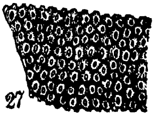

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PLATE VI.

Fig. 30.—Cross section of a secondary root; *d,* brown scaly cork; *c,* cork, the cells colored reddish brown; *k,* phellogen; *g,* cambium; the bast fibers are shown by black dots and the water tubes by circles. × 41.

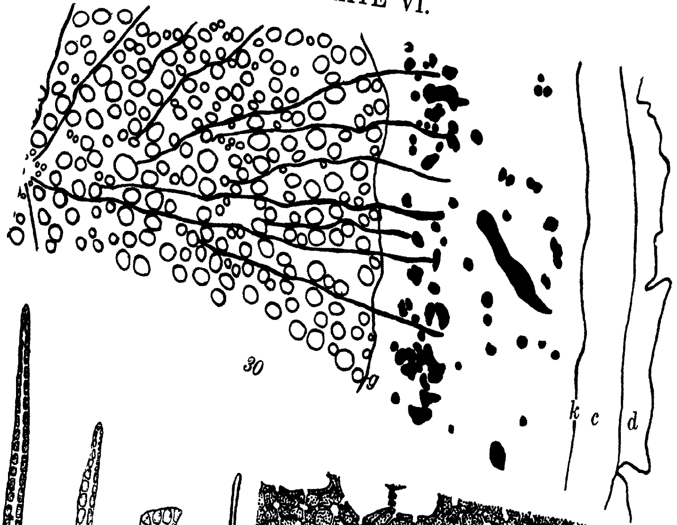
Fig. 31.—Cross section of xylem of root; *wt,* water tube; *t,* tracheid; *mr,* medullary ray. × 375.

Figs. 32, 33, 34.—Tracheids from root. × 288.

Fig. 35.—Cross section of a portion of a root; *o,* cork; *n,* phellogen; *y,* thin-walled parenchyma. × 325.

Fig. 36.—Bast fiber from root. × 180.

PLATE VI.



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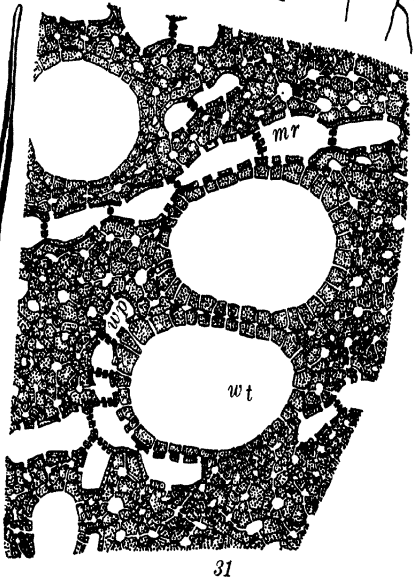

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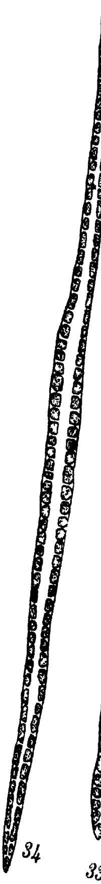

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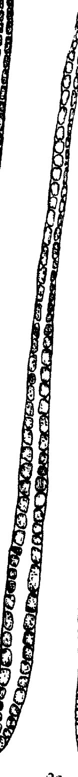

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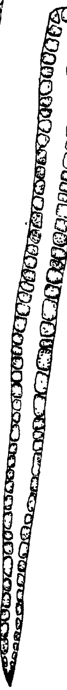

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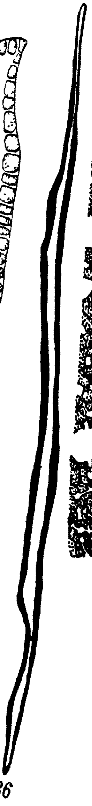

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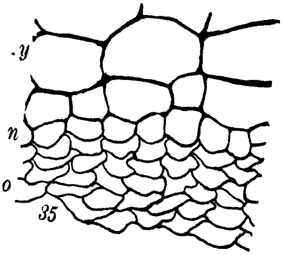

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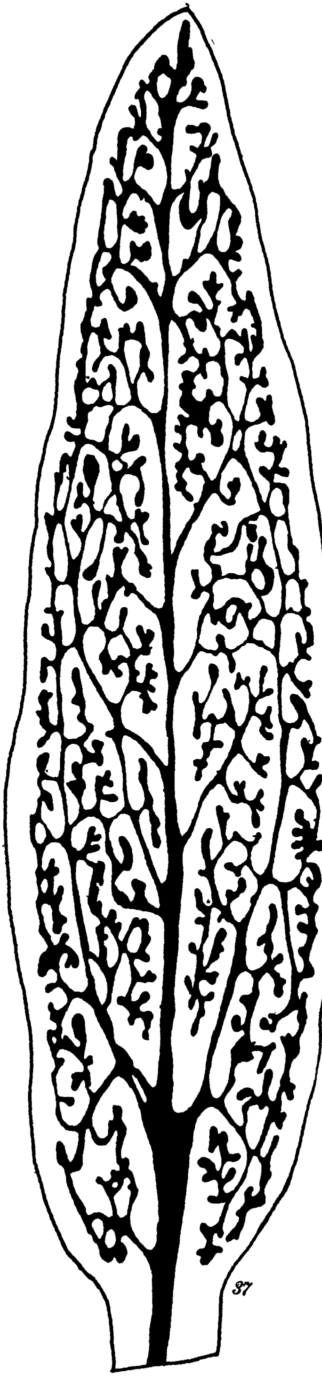
PLATE VII.

FIG. 37.—A bleached leaf, showing the venation. × 22.

FIG. 38.—Cross section of a leaf. × 120.

PLATE VII.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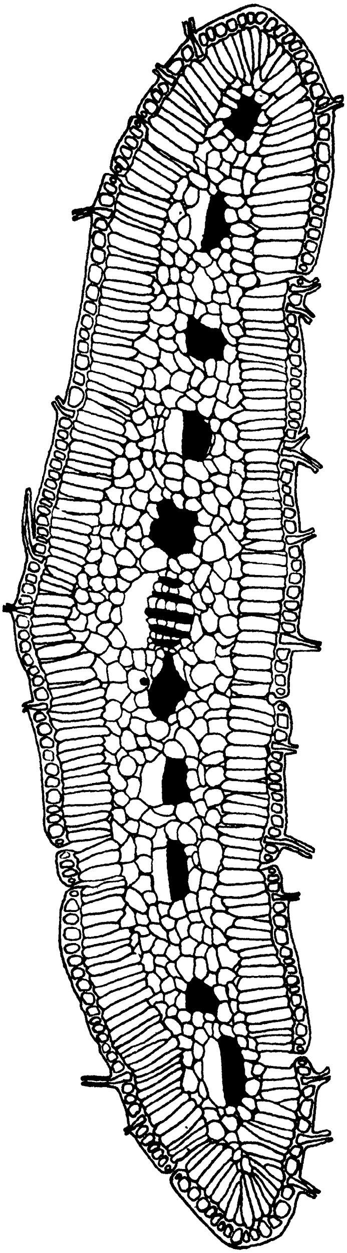
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PLATE VIII.

FIG. 39.—Surface view of leaf epidermis, upper surface: *s*, stoma; *h*, scar of trichome. × 175.

FIG. 40.—Surface view of leaf epidermis, under surface: *s*, stoma; *h*, scar of trichome. × 175.

FIG. 41.—Surface view of leaf palisade. × 325.

FIG. 42.—Cross section of a stoma, from a leaf cut longitudinally through the narrow diameter. × 475.

FIG. 43.—Cross section of the midvein of a leaf: *ph*, phloëm; tracheids shown by stippling. × 325.

FIG. 44.—Storage tracheids, from the ultimate ends of the veins of a leaf cut longitudinally through the narrow diameter. × 275.

FIG. 45.—Storage tracheids from the ultimate end of a vein of a leaf cut longitudinally through the broad diameter. × 475.

FIG. 46.—Spiral tracheid from a leaf. × 475.

FIG. 47.—Trichomes from a leaf. × 175.

FIG. 48.—Starch grains from the thin-walled parenchyma of a root. × 325.

FIG. 49.—Starch grains from the pith, medullary rays, pericycle, and primary cortex of a stem. × 325.

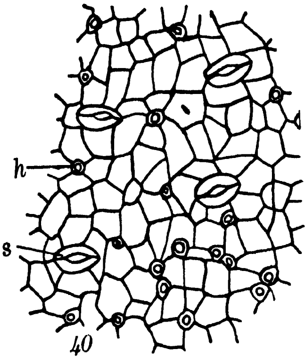
FIG. 50.—Calcium oxalate crystals from the bark of a root. × 325.

FIG. 51.—Calcium oxalate crystals: *a*, from the cortex of stem; *b*, from a leaf. × 325.

FIG. 52.—Calcium oxalate crystals from the pith of a stem. × 325.

FIG. 53.—Crystals of calcium oxalate from the phloëm of a stem. × 325.

PLATE VIII.



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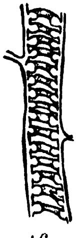

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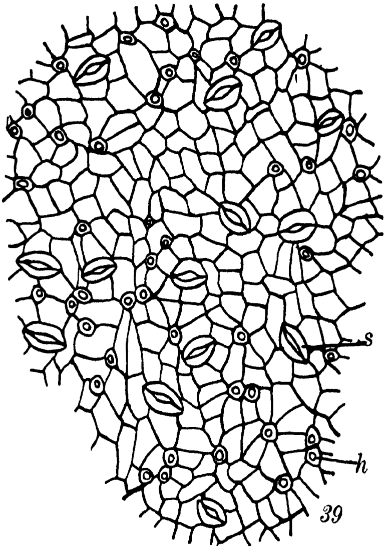

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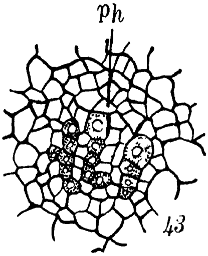

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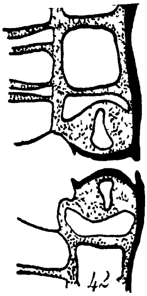

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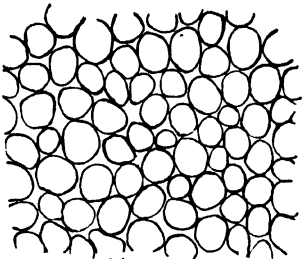

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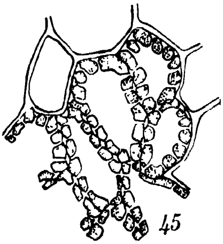

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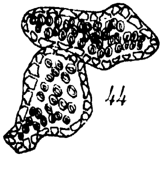

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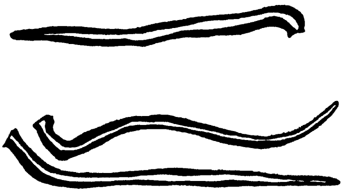

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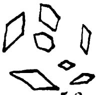

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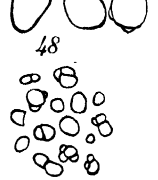

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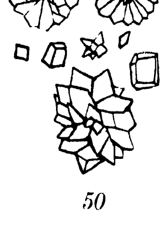

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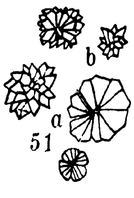

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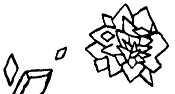

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EXPLANATION OF PLATE.

PLATE 23.

Characteristic curves of m/32 solutions. Curve approaches abscissa in relaxation.

a, Abscissa line.
d, Effect of neutral Ringer.
b, Neutral Ringer withdrawn.
e, Receptacle empty.
c, Salt solution added.
t, Time curve in 1/2 minutes.

Time and curves are reduced 1/5.

PLATE 23.

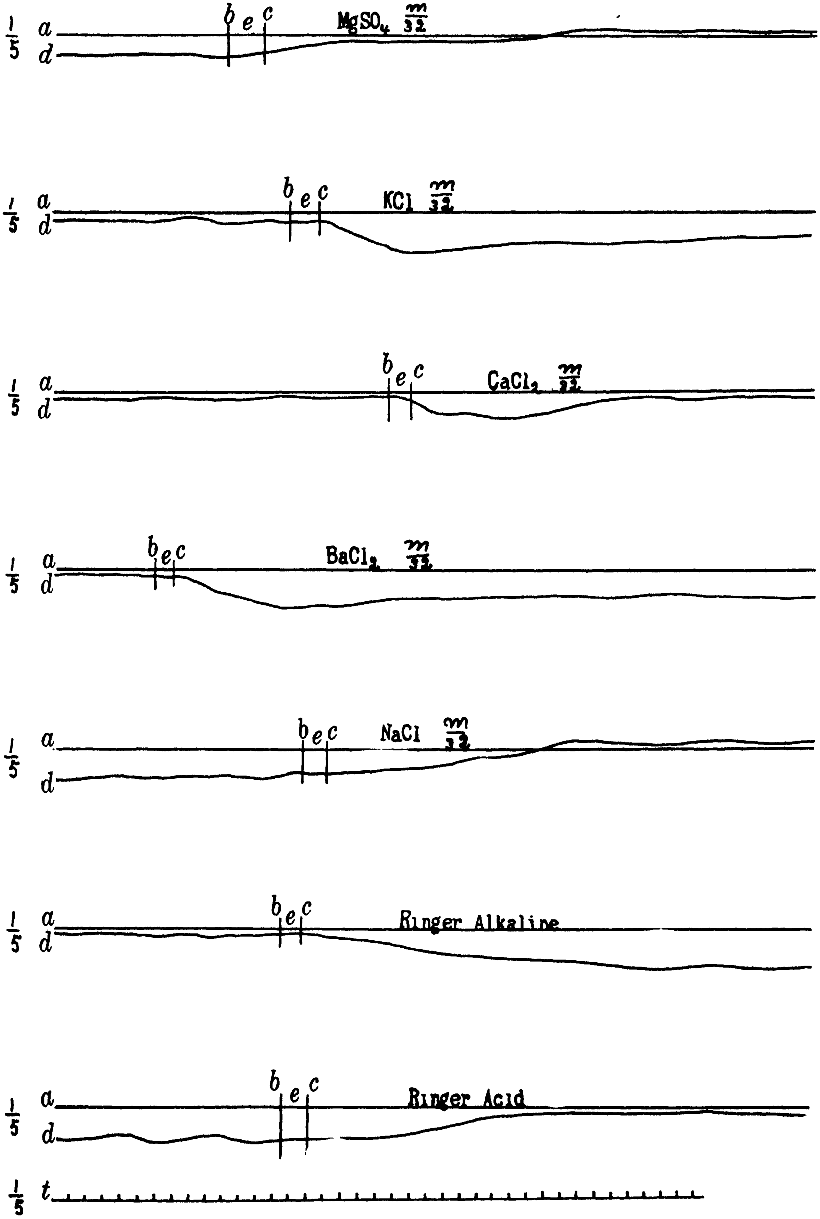
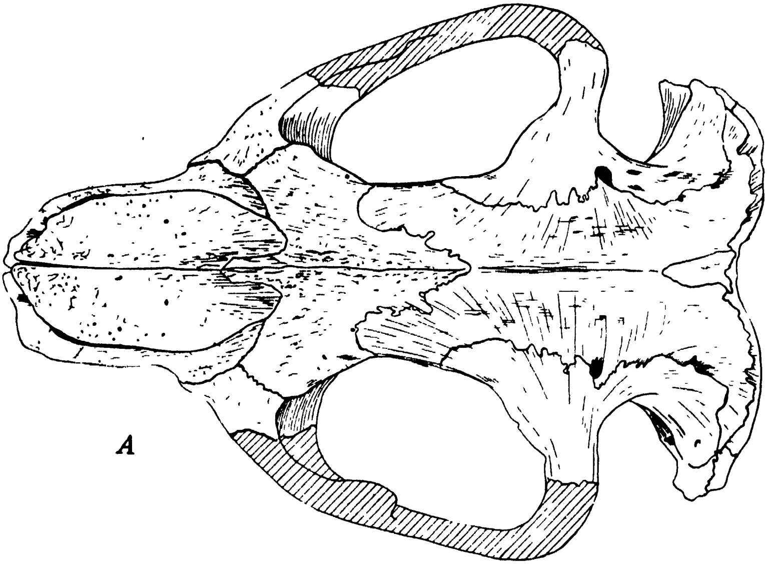

1/5 a d
b e c
MgSO$_4$ m/32
1/5 a d
b e c
KCl m/32
1/5 a d
b e c
CaCl$_2$ m/32
1/5 a d
b e c
BaCl$_2$ m/32
1/5 a d
b e c
NaCl m/32
1/5 a d
b e c
Ringer Alkaline
1/5 a d
b e c
Ringer Acid
1/5 t

PLATE 24.

FIG. A.—Dorsal view of the skull found in Lenawee county, Michigan. (No. 1634, Smithsonian collection, National Museum, Washington.) The dovetailed recess at the posterior end of the nasals is well shown, on the median line, to receive the blunt wedge-shaped portion of the frontal bone. Note the difference between this part and the nasals of the Kansas specimen.

FIG. B.—Dorsal view of the Boicourt, Linn county, Kansas, skull, showing the heavy scoring of the parietals for ligamentary and muscular attachment. Heavy line work denotes restored portions.

PLATE 24.



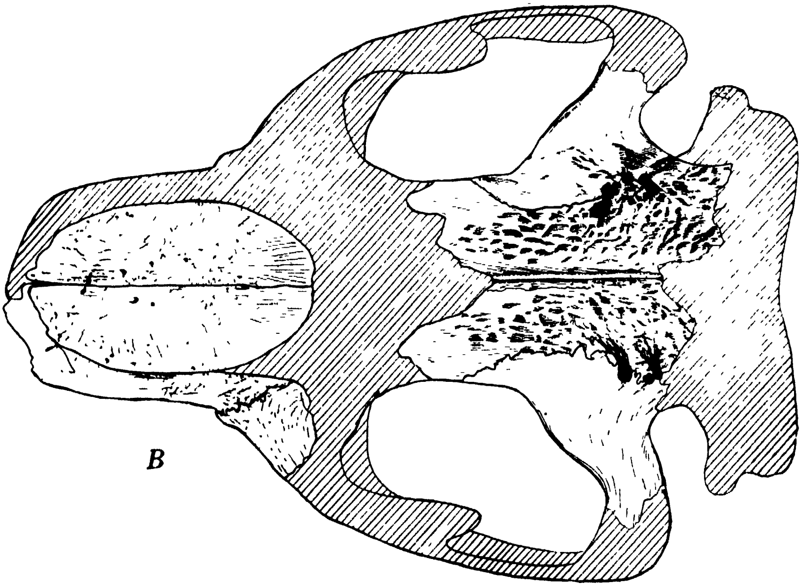
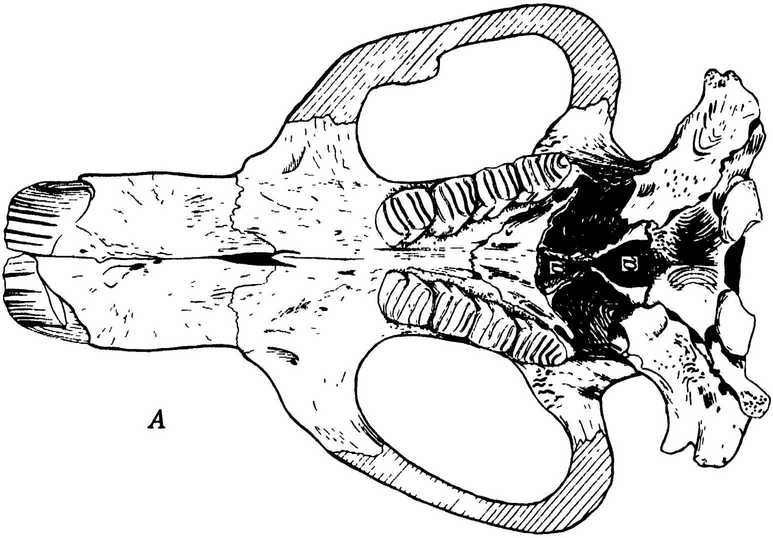


PLATE 25.

Fig. A.—Palatine view of the Lenawee skull, showing the double posterior nares, *a-a*, and the thin, laterally compressed pterygoid blades. Line work represents restored portions of the zygomatic arch.

Fig. B.—Palatine view of the Boicourt skull, with incisor removed.

PLATE 25.



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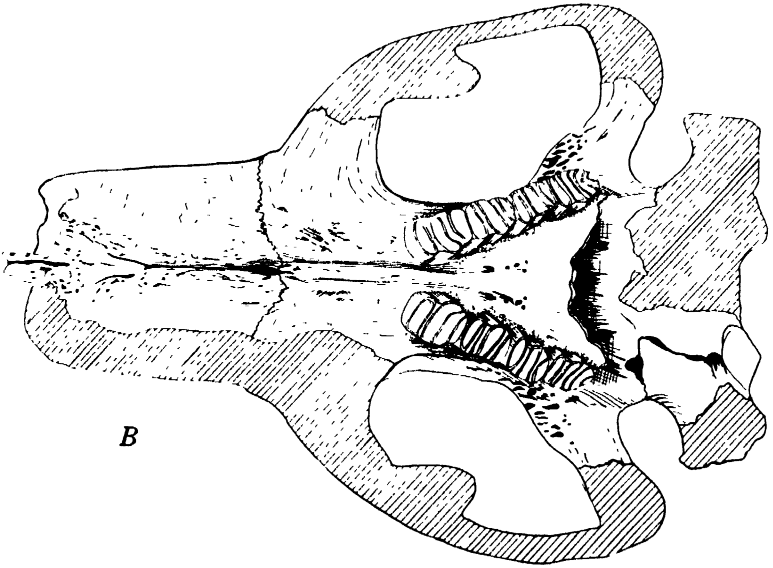


B

PLATES 26, 27.

FIG. A.—Lateral view of the Lenawee skull.

FIG. B.—Photograph of the Boicourt skull, showing the large incisor, *a*, withdrawn from its socket to show the full depth of the cavity; *c* is the frontal sinus, *d* the inner wall removed to show the last molar, *e* the very small brain cavity.

PLATES 26, 27.

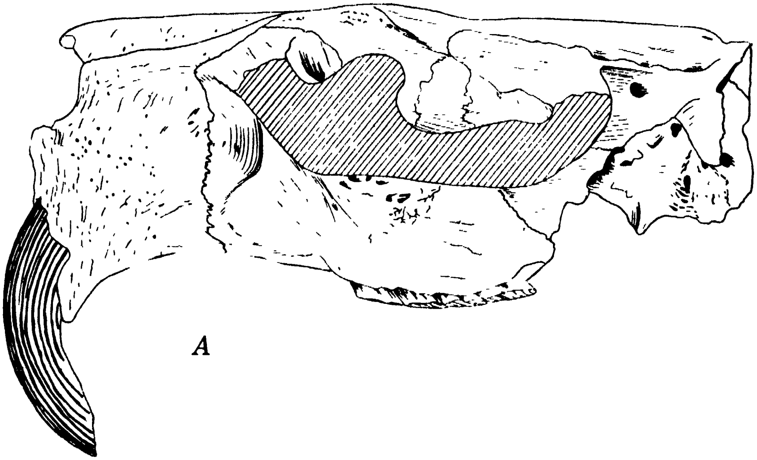


PLATE 28.

Melanoplus femur-rubrum.

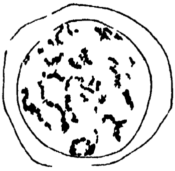
FIG. 1.—Resting spermatogonium.

FIG. 2.—Spireme stage of spermatogonium, with loops of chromatin arising from homogeneous mass of chromatin at nuclear membrane.

FIG. 3.—Further spireme stage, with tendency to longitudinal split.

FIG. 4.—Vesicular stage in late prophase of spermatogonium. Here the accessory is separated from others. Chromosomes are sometimes

PLATE 28.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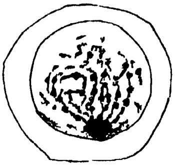
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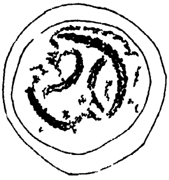
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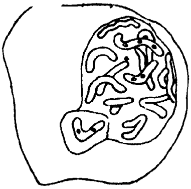
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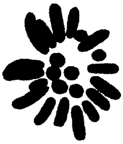
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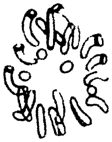
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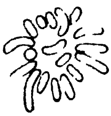
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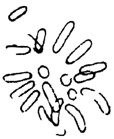
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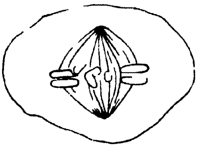
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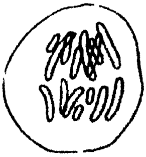
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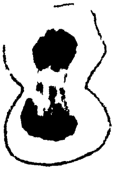
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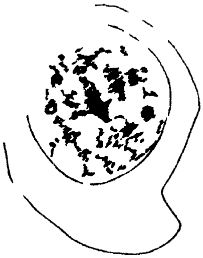
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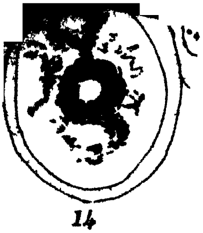
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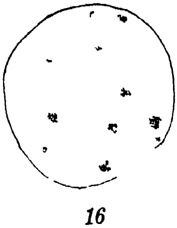
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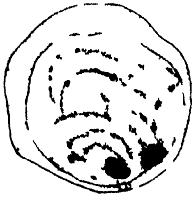
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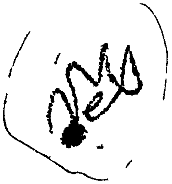
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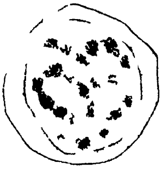
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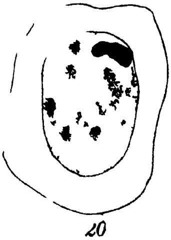
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PLATE 28.

Melanoplus femur-rubrum.

FIG. 1.—Resting spermatogonium.

FIG. 2.—Spireme stage of spermatogonium, with loops of chromatin arising from homogeneous mass of chromatin at nuclean membrane.

FIG. 3.—Further spireme stage, with tendency to longitudinal split.

FIG. 4.—Vesicular stage in late prophase of spermatogonium. Here the accessory is separated from others. Chromosomes are sometimes vacuolated.

FIG. 5.—Spermatogonium, showing the full number of chromosomes in equatorial plate.

FIG. 6.—Somatic cell from follicular epithelium, showing but twenty-two chromosomes.

FIGS. 7 to 11.—Spermatogonia, showing size and arrangement of chromosomes: Figs. 7 and 8, equatorial plates; 9, metaphase; 10, anaphase; 11, telophase.

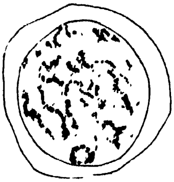
FIGS. 12, 13, 14.—Oögonia in early development: Figure 14, the follicular cells are forming around the young egg; the chromatin is loosely arranged in a ring.

FIGS. 15, 16.—Early resting phase of first spermatocyte.

FIGS. 17, 18.—Spireme stages in first spermatocyte.

FIGS. 19, 20.—Spireme has a distinctly beaded appearance.

PLATE 28.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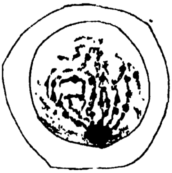
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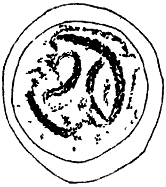
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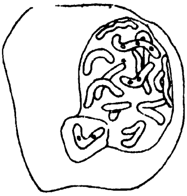
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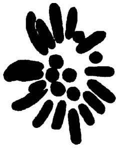
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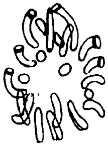
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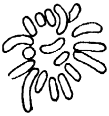
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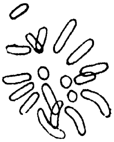
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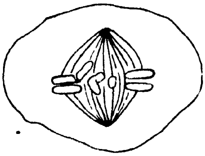
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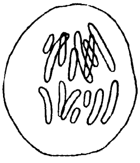
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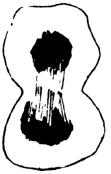
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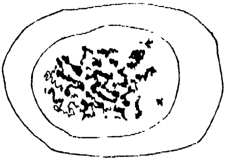
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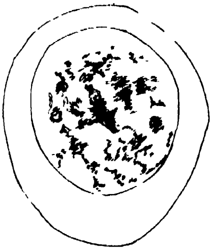
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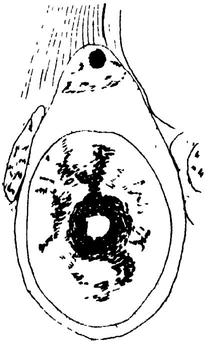
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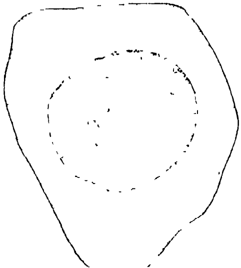
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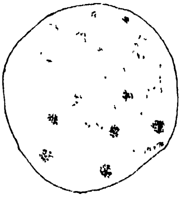
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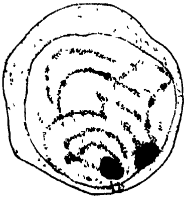
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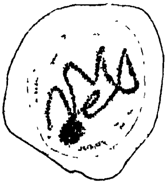
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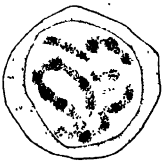
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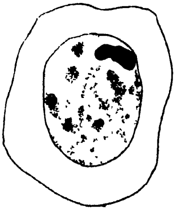
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PLATE 29.

Melanoplus femur-rubrum.

FIG. 1.—First spermatocyte, showing the centrosome in the cytoplasm.

FIG. 2.—Early first spermatocyte, showing the chromatin in large, loose rings.

FIGS. 3 to 9.—Prophases of first spermatocytes, with the ring formations and crosses.

FIG. 9.—The full number of 12 chromosomes are seen here in prophase.

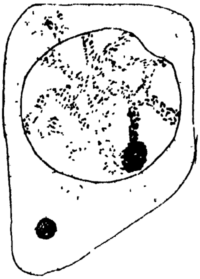
FIGS. 10 to 13.—Polar views of first spermatocyte, showing full number of twelve chromosomes and the tendency toward ring formation.

FIGS. 14 to 18.—Metaphases of firsts.

FIG. 19.—Anaphase of the first division.

FIG. 20.—Early telophase of first spermatocyte.

PLATE 29.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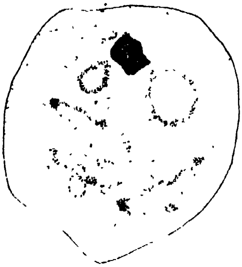
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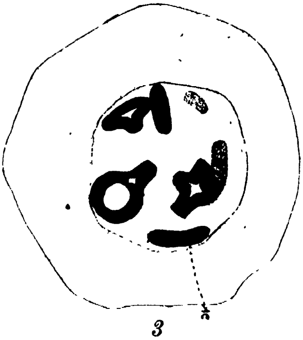

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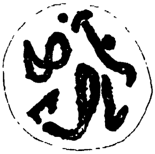
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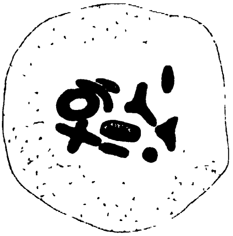
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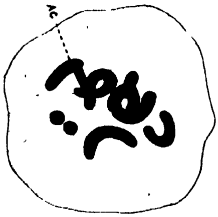

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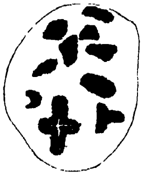
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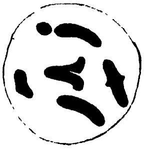
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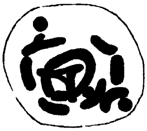
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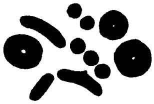
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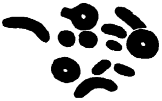
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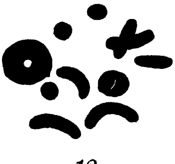
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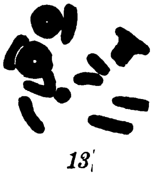
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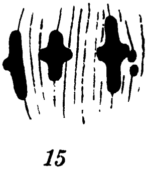
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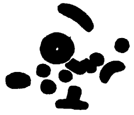
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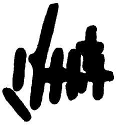
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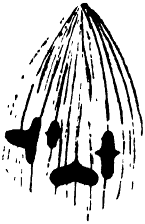
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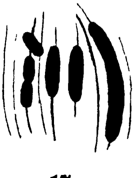
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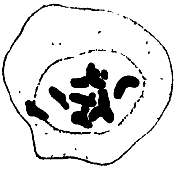
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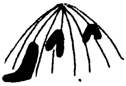
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PLATE 30.

Melanoplus femur-rubrum.

FIGS. 1 to 4.—Metaphase of first division; accessory further toward one pole than the other; arrangement of chromosomes in spindle well shown here; the early ones lying parallel with equatorial plate, and the later ones at right angles.

FIGS. 5, 6.—Metaphases of the second spermatocyte, showing twelve chromosomes.

FIGS. 7, 8.—Metaphases of second showing eleven chromosomes.

FIGS. 9, 10.—Show the early anaphase of second.

FIG. 11.—Late telophase of second spermatocyte.

FIG. 12.—Later stage still of the telophase of the second spermatocyte.

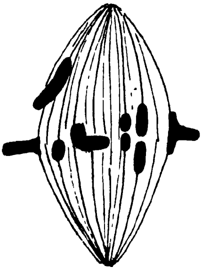
FIG. 13.—Very early spermatid.

FIGS. 14, 15, 17.—Metamorphosis of spermatids.

FIGS. 18, 19, 20.—Dwarfed spermatocytes first and second.

FIGS. 21, 22, 23, 24, 25.—Spermatids in order of development.

PLATE 30.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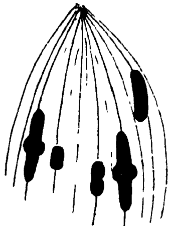
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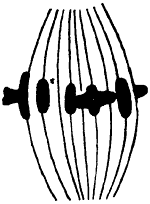
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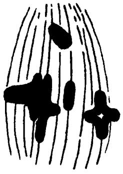
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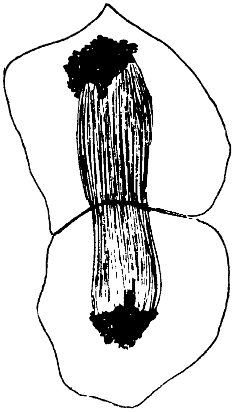
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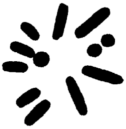
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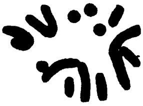
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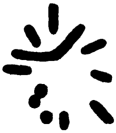
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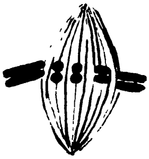
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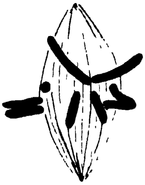
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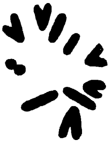
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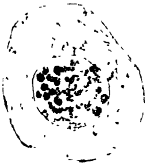
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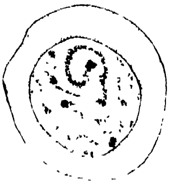
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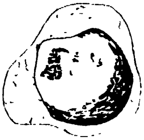
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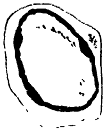
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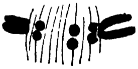
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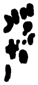
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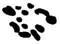
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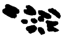
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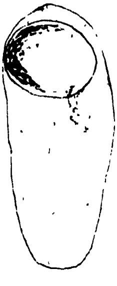
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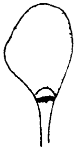
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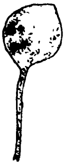
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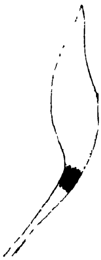
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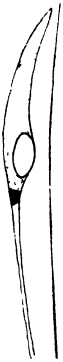
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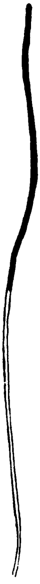
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PLATE 31.

Melanoplus differentialis.

FIGS. 1 to 4.—Spermatogonia, with full number of twenty-three chromosomes seen in equatorial plate.

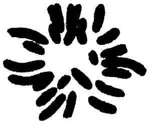
FIGS. 5 to 14.—First spermatocytes seen in equatorial plate; rings vary from one to two.

FIGS. 15, 19, 20, 21, 25, 26.—Side view of chromosomes and spindle.

FIGS. 22, 23.—Equatorial plates, with second spermatocyte from the same mother cell. One shows the eleven chromosomes while the other shows twelve.

FIG. 24.—Equatorial plate of second spermatocytes, showing twelve chromosomes.

PLATE 31.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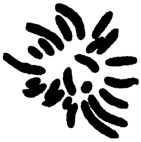
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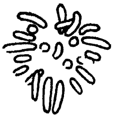
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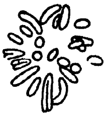
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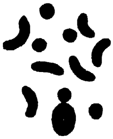
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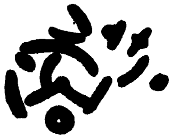
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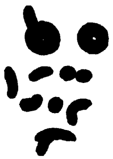
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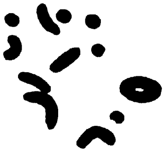
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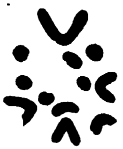
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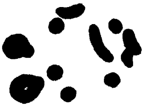
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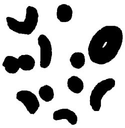
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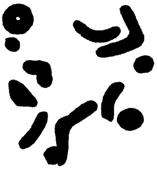
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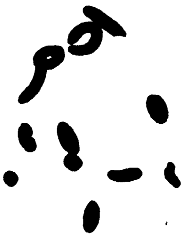
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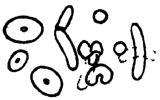
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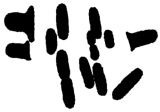
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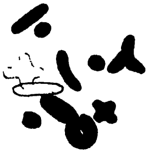
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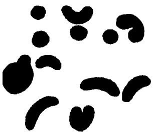
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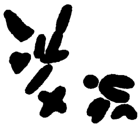
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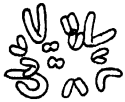
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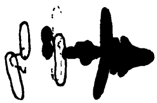
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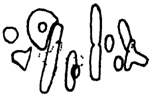
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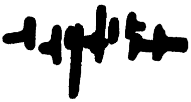
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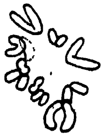
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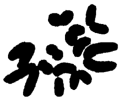
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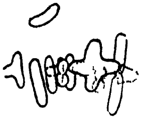
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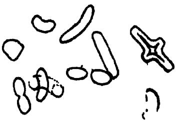
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PLATE 32.

M. atlanis.

FIGS. 1 to 12.—Stages in spermatogenesis of ***atlanis:*** Fig. 1, spermatocyte in late anaphase; figs. 2, 3, 4, prophases of first division; figs. 5, 6, 7, 8, 9, lateral view of spindle; figs. 10, 11, 12, equatorial view of chromosomes.

M. packardii.

FIGS. 13 to 24.—Stages in spermatogenesis of *packardii.*

FIGS. 13, 14.—Prophase of first spermatocyte.

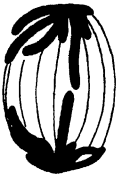
FIGS. 15, 16, 17, 20, 21.—Metaphase of first spermatocyte.

FIGS. 18, 19.—Anaphase of first spermatocyte.

FIGS. 22, 23.—Metaphases of second spermatocyte, with eleven chromosomes.

FIG. 24.—Metaphases of second spermatocyte, with twelve chromosomes.

PLATE 32.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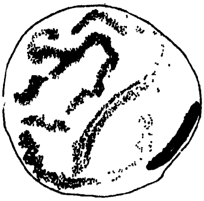
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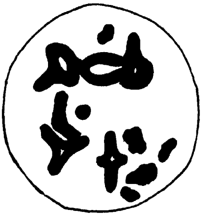
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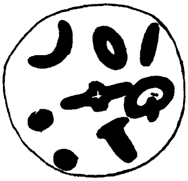
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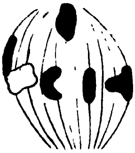
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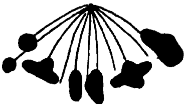
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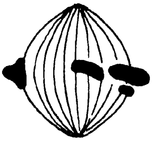
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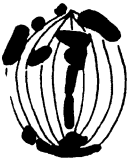
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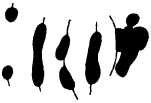
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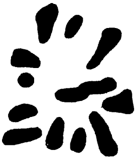
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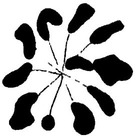
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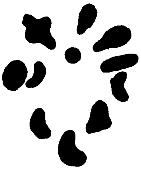
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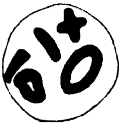
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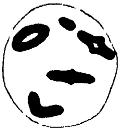
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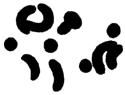
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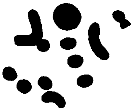
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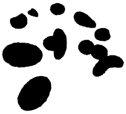
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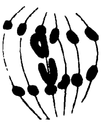
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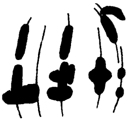
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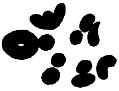
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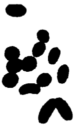
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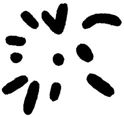
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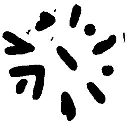
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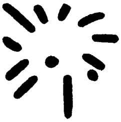
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